MANPOWER AND FACILITY MIXES IN A DENTAL PRACTICE:
A SIMULATION ANALYSIS

A THESIS

Presented to

The Faculty of the Division of Graduate

Studies and Research

By

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In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in Industrial and Systems Engineering

Georgia Institute of Technology

December, 1973

MANPOWER AND FACILITY MIXES IN A DENTAL PRACTICE:

A SIMULATION ANALYSIS

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ACKNOWLEDGMENTS

The author wishes to express his gratitude to the many individuals who have contributed to this work. Particular appreciation is extended to Drs. J. B. Mathews, the author's thesis advisor, and R. M. Bramblett for their guidance and encouragement throughout this effort and to Drs. D. W. Heid and T. L. Sadosky for their helpful comments in reviewing this work.

The author gratefully acknowledges the cooperation and assistance of Dr. Heid and the faculty of the School of Dentistry at the Medical College of Georgia who willingly and unselfishly encouraged and assisted the author throughout this research.

Special thanks are given to Dr. Harold E. Smalley, Director of the Health Systems Research Center and to Dr. J. B. Mathews, Director of the Division of Systems & Computer Services, for providing throughout the author's graduate studies timely financial support and encouragement.

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SUMMARY

This was a study aimed at providing dental researchers and practicing dentists a means of identification of that manpower and facility arrangement which is most suitable to their needs in terms of net income and other design criteria. Specific objectives of the study were to:

1. Develop an evaluation methodology for investigation of dental TEAM composition, the number of operatories, and the various input factors in solo dental practices.

2. Demonstrate the evaluation methodology on national average input date to determine the adequacy of the methodology as a predictive and evaluative tool.

3. Investigate the results of the demonstration in terms of the general implications of including expanded-function dental ancillary personnel in private solo practice.

Systems description and data collection of the system investigated were performed followed by development of a cost model and an allocation and routing model. The general simulation model was then constructed and validated. An experiment was designed to permit the prediction of the performance of the system under the decision factors of interest and to allow statistical evaluation of the changes that occur in net income and the secondary performance measures as one or more of the factors were varied.

A set of decision variable levels and input parameter levels representing national average data were used in demonstrating the simulation model and analysis techniques. Analysis of variance and a multiple range technique were used to evaluate the results of the demonstration.

The application of the demonstration indicated that the methodology developed was adequate for simulating and evaluating various levels of decision variables and input parameters.

The analysis of demonstration results with regard to EFA utilization in solo practice indicated that some upward personnel substitutability was a significantly better operating policy than was strict adherence to personnel skill inventories. The results also indicated that solo TEAM practices with two or more chairside assistants yielded the significantly greatest net incomes.

This investigation was concerned with developing an evaluation methodology for a specific class of solo TEAM dental practice. Although the factors that define dental practices may vary somewhat, the techniques of data collection and application of the methodology developed herein could be applied to the analysis of a variety of dental practice arrangements. Suggestions for appropriate follow-on research in dental practice management are presented as study recommendations.

CHAPTER I

INTRODUCTION

The purpose of this research was to enable practicing dentists and dental researchers to identify that manpower and facility arrangement which is most suitable to their needs in terms of net income and other design criteria. Specific objectives of this research were:

1. To develop an evaluation methodology for investigation of dental team composition, the number of operatories, and various input factors in solo dental practices,

2. To demonstrate the evaluation methodology on national average input data to determine the adequacy of the methodology as a predictive and evaluative tool,

3. And, to investigate the results of the demonstration in terms of the general implications of including expanded-function dental ancillary personnel in private solo practice.

Efficient operation of a private dental practice requires that personnel, equipment, and material be available when and where they are needed. Today's increasing demand for services from the dental care delivery system has caused dental health care planners to investigate alternative methods of increasing the supply of dental services to meet this rising demand. Increases in the annual number of dental graduates alone does not seem to offer a good solution to the dental service demand-supply gap [25].

One of the more promising methods for increasing the productivity of the dental health care delivery system has been the introduction of various types of auxiliary personnel to assist the dentist. However, the assistant alone has not increased dental productivity sufficiently to alleviate the demand-supply gap. Recognition of this fact has focused professional attention on the clinical team concept - the efficient chairside use of relatively independent expanded function auxiliaries (EFA). Delegation to those auxiliaries of various dental procedures which do not require the professional skill and knowledge of the dentist would logically result in more efficient use of the dentist's time and would tend to increase the production of the team.

The Specific Problem

A major problem associated with the use of expanded function auxiliaries lies in determining the optimal composition of the team and number of operatories in a dental practice and adequate criteria and associated measures for assessing real changes in productivity. Unless the supply of manpower and facilities in a dental practice are equal to the demand for service in that practice serious economic implications may result. If the supply of service exceeds the demand for service, the high cost of overhead and personal labor cost will be incurred by the practice. On the other hand, if the demand for service exceeds the available supply many users of the dental system will be denied adequate dental services. In any event, excessive supply or unmet demand can have a detrimental effect upon the dental health system.

Although the demand for dental services cannot be known in advance, a large number of observations or historical services rendered will frequently give a reliable distribution of demand data. From this, a statistical model can be synthesized which will predict the behavior of the demand for a service.

Services provided by a dentist, due to their standard and repetitive nature, can be probabilistically represented as a distribution having a mean and a variance. With these data it is possible to ascertain the supply and arrangement of resources required to meet the demand placed upon a dental practice.

Assumptions

A quantitative cost model based on variable and fixed cost and revenues from services rendered will reliably serve as a performance indicator to evaluate various levels and mixes of manpower and facilities in a dental practice.

A specific service rendered by either the dentist or the auxiliary is of acceptable quality and of equal duration.

The statistics derived from typical dental practices may be properly utilized in the development and validation of the methodology developed herein.

Method of Procedure

The study objectives were accomplished through the development of a computer simulation model incorporating various levels and mixes of inputs of manpower and facilities, and a sequence of various evaluation techniques used to select the optimal mix of the input quantities for the demonstration. The method of procedure followed in the course of the study is described in the following paragraphs.

Phase I - Literature Search and Interview

The background information necessary to conduct the study was obtained via an indepth search of the literature of EFA, TEAM dentistry, and four-handed dentistry applications and evaluations. This information was supplemented by interviews with knowledgeable EFA-related personnel, including practicing and teaching dentists, EFA's, dental health care planners, and dental patients. The results of this information collection phase was documented in a state-of-the-art-literature survey on the status of EFA feasibility, efficiency and techniques. Also, a literature search was conducted to ascertain the state-of-the-art of computer simulation analysis applied to health care delivery.

Phase II - Systems Description and Model Formulation

The information gathered in Phase I was consolidated for use in the study. A logical model representing an "average" solo dental practice, with flexibility to incorporate various levels and mixes of auxiliaries and operatories was constructed as the basis of the simulation model. Systems variables and parameters were identified.

Phase III - Model Validation

The logical simulation model was translated into an appropriate computer language. Two types of confirmations were undertaken, verification and validation. Verification consisted of syntax and logical error location and correction within the model program. Validation was accomplished by comparing statistically the model performance and sensitivity with know data and results. Any major non-random deviation from the expected results was investigated by statistical methods and the source of error adjusted.

Phase IV - Model Demonstration

The model constructed in Phase II and validated in Phase II was used to simulate and evaluate selected levels of decision variables and input parameters according to a chosen criterion for an "average" solo TEAM practice. When the various mixes of manpower and facilities were simulated, an evaluation of statistical and general inferences of the results was performed.

Phase V - Discussion and Conclusions

The modeling and evaluation methodology and its demonstration were discussed in light of the model operation, the characteristics of the system under study, and the assumptions made in the study. From this, a set of conclusions and areas requiring further investigation are offered.

Scope and Limitations

This research was primarily concerned with the modeling and evaluation of solo TEAM dental practice. Hence, the methodology developed herein is only directly applicable to such a system. In general, it is not applicable to specialty or group practice. However, since the solo dental practice is the predominant method of dental health care delivery, this methodology should have widespread application.

This study focuses on the relationship of specific measures of effectiveness to the variation of the input variables. It makes no attempt to incorporate measures relating to the patient's perception of the quality of dental care. Specifically, factors such as a high quality service, the establishment of patient-dentist rapport, and total patient satisfaction are not included as evaluation criteria. The primary criterion for the optimization of manpower and facility mixes is net income of the dentist prior to taxes. If nonmonetary considerations are of significant consequence, the economic optimum may not be the most desirable alternative.

The methodology developed in this research could be applied to a specific private solo practice if the appropriate data (arrival distributions, fees and fixed and variable costs, personnel configurations, etc.) were collected and adapted for use. The intent of this research was to develop a methodology which would be particularly applicable to certain resource allocation problems of dental private practice management, and no attempt has been made to illustrate applications in other areas of the dental care delivery system (such as group practice or open clinics).

The methodology developed herein was intended for future use by dental researchers and analysts. Typically, a practicing dentist could not apply the methodology without consultation from a person with knowledge of computer simulation, statistics, and other advanced applied mathematical techniques. The methodology assumes that appropriate input data have been collected and adapted for inclusion in the simulation model. The output of the methodology gives the user data for use in making his choice as to the "best" configuration of resources.

In the following chapter, a review of selected literature is presented in order that the progress, the problems, and the contributions of researchers in this area of dental practice management systems may be appreciated.

CHAPTER II

SURVEY OF RELATED LITERATURE

Introduction

A review of the literature in the health field indicates a widespread interest in the development of auxiliary manpower to supplement directly the physician and dentist in the delivery of health care. The strong current interest in dental auxiliary personnel arose due to the increasing disparity between dental care demands and the ability of existing numbers of dental personnel to meet these demands with conventional methods. The literature gives considerable emphasis to reporting general descriptions of individual manpower development projects, problems encountered in training and using ancillary personnel, and future expectations of dental auxiliary manpower development. These writings give a contemporary view of the general role and potential contributions of dental auxiliary manpower; however, few planning and evaluation aids to guide prospective employers on the utilization of dental auxiliary manpower are available in the literature.

The dental auxiliary planning and utilization problem is similar in some respects to certain classes of problems that have been dealt with previously in other areas of the health field. Specifically, computer simulation methods have been successfully used to develop hospital outpatient department patterns, staffing, patient appointment, schedules, and facilities plans.

Definitions

The literature contains a wide variety of job titles for dental auxiliary personnel. Similarly, a few basic organizational concepts for the delivery of dental care frequently assume a variety of aliases. Traditionally, there have been three principal allied occupational groups in dentistry: dental chairside assistants, dental hygienists, and dental laboratory technicians.

Dental chairside assistants aid the dentist at the chairside by preparing the patient for treatment, keeping the operating field clear, mixing materials and passing instruments. Other duties involve exposing and processing radiographs, sterilizing instruments, assisting with laboratory work, ordering supplies, and handling the office records and accounts. More than 85 percent of the dentists in private practice now employ one or more full or part-time dental assistants [12].

Dental hygienists provide oral health services directly to the patient, thus, requiring a state license to practice. The hygienist, working under the direction of the dentist, performs prophylaxes (scaling and polishing of teeth), exposes and processes dental radiographic films, applies fluoride solution to the teeth, and instructs individual patients in tooth brushing techniques and proper diet as related to teeth.

The dental laboratory technician is a skilled craftman who performs many tasks involved in the construction of complete and partial dentures, fixed bridgework, crowns, and other similar dental restorations and applicances. The technician ordinarily does not have direct contact with the patient, but performs his work in accordance with the instructions received from the dentist.

A new ancillary occupational group, the expanded function auxiliary (EFA),* works directly with the patient and performs a number of reversible procedures traditionally performed by the dentist. The procedures may include the application of rubber dams, placing matrix bands, carving and finishing amalgam restorations, placing and finishing silicate and acrylic restorations, and placing temporary cements [19]. Other duties that have been delegated to the expanded function auxiliary include: selection, adaptation, and cementation of stainless steel crowns; fabrication of space maintainers; taking alginate impressions for and preparing study models; prophylaxis and application of topical fluoride [26].

Closely related to the introduction of expanded function auxiliaries into the dental practice is the four-handed, sit-down dentistry concept. This concept grew from the Dental Auxiliary Utilization (DAU) Program sponsored by the Federal Government. The background of DAU is noted by Heid [10] who states:

> Recognizing the need for dentists to use assistants more in their offices and recognizing also that men already in practice might not be easily convinced that a change would be for the better, the United States Public Health Service, Division of Manpower and Resources, proposed a pilot study in 1956. This pilot program consisted of 6 selected schools chosen to initiate a means of instructing dental students how to work

*This new occupational group currently has several acronyms including EFA, EDA, and EDDA. This study will use the term EFA for describing this type of ancillary person.

with a trained dental assistant. From the modest beginning in 1956, today's program involves all of the dental schools in the United States.

This DAU Program has recently been altered to include training of the expanded function auxiliary as a member of the dental care delivery system. Federal support for research, experimentation, and development of these activities has been provided to schools who participate in the new TEAM Programs. ("TEAM is an acronym for Training in Expanded Auxiliary Management") [9]. The TEAM concept at the Medical College of Georgia School of Dentistry, "envisions two or more dentists sharing common facilities and services in an environment of expanded duty auxiliaries utilizing DAU principles" [10]. Expanded function auxiliaries will perform under direct supervision of the dentist, who in turn will be responsible for the diagnosis, treatment planning, and non-reversible procedures.

Background

There is a disparity between present and anticipated dental care demands and the dental professions ability to meet these demands with contemporary methods [11]. Consideration of alternatives to conventional approaches has led dental health and manpower planners to support programs and policies relating to expansion of duties and training opportunities for auxiliary personnel. Specifically, it was proposed that evaluation projects be developed to study the extension of duties that could be delegated to the dental chairside assistants and hygienists [22].

A comprehensive survey of the literature by Hammons [13] indicated that expanded duty delegation to auxiliaries is not new. The first documented experience of formal programs of EFA utilization occurred in New Zealand in 1921. The New Zealand government instituted a program in that country's dental schools to begin training dental nurses to provide dental care to school age children Rosenblum [26] notes,

> After a two-year training period, dental nurses made examinations and diagnoses, planned treatment, gave prophylaxes, topical fluoride applications, and local infiltration anesthesia, prepared cavities, placed "uncomplicated" restorations, extracted deciduous and permanent teeth under local anesthesia, and took part in dental education.

In Great Britain the General Dental Council was charged with the responsibility of developing an experimental program to train and employ dental auxiliaries and to determine their effect on the community dental profile [13]. The training program was initiated in 1960 and like the New Zealand program, consisted of a two-year course of study. The dental auxiliaries were trained to place simple restorations, extract deciduous teeth, and give prophylaxes under the supervision of dental officers [26].

In New Zealand, Norway, and the United Kingdom, the dental care planners recognized the imbalance between the need for dental care and the availability and utilization of dental services. Norway's available dental manpower was adequate to supply the population's needs. However, the major problem was to convert the needs to effective demand by promoting oral health awareness and in turn distribute dental services to the entire population. In New Zealand, the insufficient quantity of dental manpower would have been unable to accommodate the population's dental care needs if it were converted suddenly to effective demand. Hence, planning was required to develop the new manpower to supply the dental services to that country. Similarly, in the United Kingdom, there was an adequate supply of dental manpower to meet the dental needs to the population if the need were converted to demand. The initial United Kingdom plan was to increase dentist education programs to meet the anticipated demand. However, it was recognized later that expanded function delegation to dental auxiliaries would substantially alleviate the dental manpower shortage [13].

A program in 1959 initiated by the United States Navy trained dental technicians to provide expand dental functions for adults in the United States Navy. The auxiliaries placed rubber dams, inserted bases or liners or both, placed matrix bands, and packed and carved restorations [13].

In the Naval experimental program, various combinations of chairs and technicians were investigated to determine empirically the optimal number of technicians and chairs a dental officer could use efficiently without excessive fatigue for either the dentist or technician. It was found that the most efficient combination was one dentist, three chairs, and four technicians [13]. It was shown that, without a decrease in quality, the quantity of service delivered doubled for the team as opposed to the dentist operating alone [26].

In 1961, the Royal Canadian Dental Corps initiated an expanded utilization program for dental hygienists. After a 16 week training period the therapists were required to perform expanded functions as directed by the dentist. The team consisted of a dental officer, a therapist, a chairside dental assistant, a roving assistant, and a clerical assistant. Delegated duties assigned to the therapist include: application of the rubber dam; selecting, contouring, placing, and removing of matrix bands; packing, carving, and finishing amalgam restorations; placing and finishing silicate and acrylic restorations, and placing, carving, and finishing various types of temporary cements. Additional delegated procedures included taking impressions for study casts; taking final impressions; taking simple interocclusal records, and selecting tooth shade. In the area of complete denture prosthodontics, additional functions including taking preliminary impressions and taking preliminary bite relations were delegated. The trainee also learned how to place periodontal packs and give instructions on home care, in addition to prophylaxis and scaling for which the basic clinical technician had been previously trained [13]. From this study, it was concluded that in the treatment of adult patients, the group production of the experimental team was almost 100% greater than that of the conventional dental officer-hygienist team. [26]

The Division of Indian Health of the United States Public Health Service reported, in 1966, an experimental study to determine the ability of dental assistants to perform functions that traditionally had been performed by the dentist only. Four dental assistants were trained to perform expanded functions in this study. The dental assistants were trained to perform the following functions: selecting, contouring, placing, and removing matrix bands; placing the alloy, and carving Class 2 restorations. Each restoration placed by an assistant was checked by a dental officer [26].

A study carried out at the University of Alabama from 1964 to 1966 was designed to determine the potential capacity of specially trained dental auxiliaries to perform some of the operations traditionally performed by the dentist only. In this experiment, functions delegated to the assistants were: taking impressions for study casts, placing rubber dams, placing temporary restorations, placing matrix bands, condensing and carving amalgam restorations, and applying the final finish and polish to restorations. Selected female high school graduates participated in a two-year training course which included basic sciences and pre-clinical technique, advanced pre-clinical instruction, and supervised clinical training. The findings of this study indicated that trained auxiliaries performed the delegated functions as well as advanced undergraduate dental students [14].

In the early 1960's the United States Public Health Service started planning the Louisville Study. The study was carried out in three phases. The purpose of phase one was establishment of a base line of proficiency against which the performance of experimental teams would be measured with regard to quality and productivity of service. In phase two, the dental assistants were specifically trained to perform certain selected procedures delegated in the experimental phase of the project. In phase three, the experimental teams worked in a patient service program and each team was measured for comparison with the base line data. Typical functions delegated on the auxiliaries included: charting and radiographs, rubber dam application, saliva ejector application, removal of temporary fillings and alginate impressions; matrix placement, amalgam or synthetic placement, carving and polishing of amalgam restorations, finishing synthetic restorations, and placing temporary fillings; instructions to patients with new dentures, and polishing of dentures [14].

Results of the study indicated that expanded function auxiliaries can perform delegated duties with an acceptable level of quality. However, results of this study were inconclusive as to the appropriate team size and composition for optimal efficiency and productivity. As a recommendation for further study, it was suggested that experimentation with one or two auxiliaries performing expanded duties in a private dental practice be investigated.

From the foregoing review it is clear that the feasibility of expanded utilization of dental auxiliary personnel has been widely considered. However, the specific implication of various forms of EFA utilization in dental practice are not yet clear. Rosenblum [26] notes:

> Trainees used in experimental programs had great diversity of background and experience in dental qualifications. Furthermore, studies vary widely in their reports of the quality and quantity of clinical procedures rendered by such personnel. Before the widespread introduction of training programs is possible in the United States, it is apparent that several aspects of such training need clarification. These include the qualifications required of trainees, the type and extent of training indicated for the duties delegated, and the closeness of clinical supervision required. In addition, there is clearly a need for the establishment of reproductable criteria for the evaluation of quality and quantity of procedures performed.

One method of analyzing a variety of EFA configurations economically is to develop a mathematical model of the TEAM dental practice and study the behavior of the model with regard to changes in various variables. This analysis technique, called model simulation, allows the modeler to describe and evaluate real world situations which would otherwise be difficult or costly to construct or to experience physically.

Simulation

Health care on a mass basis is becoming more important as our population increases in size and tends to concentrate in urban centers. As the available supply of medical and paramedical personnel are asked to perform more services, the clinical team approach to health care delivery is gaining popularity. This suggests that operations research analysis might aid in finding a near optimal allocation of health professional personnel, auxiliaries, technicians, and other supportive personnel. Such a situation is reminiscent of the classical economic problem of allocation of scarce resources among competing users.

There are several resource allocation techniques which could be applied to a situation as described above. Four possible techniques which might be employed are linear programming, dynamic programming, queueing theory, and simulation.

Some factors which are important in the analysis technique chosen for use in the methodology are:

1. The technique should be extremely sensitive to the interdependencies and stochastic processes involved in general dental

practice.

2. The technique should be capable of including a variety of costs and revenue associated with the economics of general dental practice.

3. The technique should be well understood and give meaningful results consistent with real situations.

Linear programming deals with allocation of resources among competing activities. However, the non-integer solutions* and non-varying constraint coefficients over the entire range of each variable make linear programming appear to be an undesirable technique for use in the methodology development.

Dynamic programming, in general, does not have a standard mathematical form. It is usually applied to problems which can be divided into chronological stages. Also, dynamic programming is typically applied to problems in which the decision stages are independent of each other. It is obvious, however, that the stages and factors of general dental practice are highly dependent and that dynamic programming may be eliminated as a possible technique.

Queueing theory can be used to develop mathematical models of transactions being served in service channels. However, interactions of servers cannot be identified with this technique. But, queueing theory is desirable for inclusion in the final technique chosen for use in the methodology.

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*Integer programming is another mathematical programming technique which gives integer optimal solutions, but the solution algorithms to date are limited and inefficient.

Simulation, with sufficient sample size, can adequately represent actual events and give results that are consistent with those from more rigorous analytical techniques [28]. One of the first attempts to apply a simulation technique in the health field was reported in 1959. A manual simulation was used to evaluate a proposed change in the pattern of patient flow in an outpatient clinic under certain assumed conditions of patient input [16]. Simulation has also been used to aid in facilities planning processes in hospitals. Most attempts have concentrated upon forecasting the number of examining or operating rooms which would be required to effectively process a predicted number of patients [24]. Several other studies have used simulation to analyze alternative appointment systems of patient scheduling in outpatient clinics [16,18,24,27].

Research experience has been accumulated in the simulation of health care systems that have characteristics similar to those present in a private dental practice. Hennessee [15] investigated the relationship between the time spent by patients in obtaining medical services and the alternative staffing levels, policies, and projected operating conditions in a large outpatient clinic. The intent of this investigation was to provide an analysis which would assist hospital management officials in making decisions in an attempt to improve the service characteristics of the system. However, since many outpatient clinics operate in a similar manner, the method of approach should be applicable to the analysis of many different outpatient operations. It can be assumed that typical general private dental practice has many of the operational characteristics of an outpatient clinic.

Therefore, the methods of systems simulation studies conducted in an outpatient setting could be extended to the private dental practice.

Most recently, Delaney [6], has completed a simulation analysis of extended function auxiliaries in general dentistry. A simulation model of a general dental practice was developed to investigate the effect of employing alternative numbers of extended (expanded) function auxiliaries of like skill levels upon certain measures of system effectiveness. The model was based on task descriptions for the majority of the procedures commonly found in general practice. Task time probability distributions were determined from data previously collected in the Louisville Experiment. Variations in auxiliary skill level, the number of auxiliaries, and the ratio of auxiliaries to operatories were studied.

Delaney drew several interesting conclusions from his work. His results supported his hypothesis that substantial increases in effectiveness can be obtained through the utilization of extended function auxiliaries. Also, he demonstrated that the increase in volume and the decrease in cost of services can be accomplished without increasing the burden upon conventionally trained professionals.

In his thesis, Delaney chose to fix the skill inventory of all auxiliaries identically. This assumption removed any task distinction among the hygienist, the chairside assistant, and the expanded function auxiliary. The TEAM philosophy of EFA utilization, however, dictates that EFA's augment and supplement the dentist and chairside assistant duties while concurrently assuming the duties of the hygienist. It therefore seems imperative that experimentation with auxiliaries of varying skill inventories be initiated to determine and develop practical standards for EFA utilization in private dental practice.

The results of the literature survey indicated a widespread interest in the analysis of expanded functions auxiliary utilization. However, adequate evaluation criteria for assessing real changes in productivity and production have not yet been identified. Although the problem presented by varying the skill inventory of the auxiliaries was identified, mixed skill levels for the various alternatives were not considered. The study described herein attempts to investigate the operating characteristics of a solo dental practice utilizing EFA and chairside assistants. Specifically, a methodology for the determination of a near optimal manpower and facilities arrangement in a typical solo dental practice was accomplished via a computer simulation model and two analytic techniques. In addition to providing information for use in dental practice management, the methodology developed should be of general interest due to the lack of published material relating to variation of EFA skill inventories.

CHAPTER III

SYSTEM DESCRIPTION

General Description

The dental services team concept modeled in this study is largely experimental and idealized. Although training and planning for the proposed dental care delivery team are ongoing, implementation has not occurred outside an experimental clinical setting. This research addresses itself to an analysis of the potential contribution of various forms of the TEAM concept in the general solo dental practice.

The TEAM dental practice examined in this study is in many ways similar to the existing general practice. Differences arise due to certain possible changes in the philosophy of dental care delivery and techniques. The following sections describe respectively the existing typical dental practice and one form of proposed TEAM practice.

Description of Existing Dental Practice

The most prevalent method of dental care delivery is the general private practice. Within this category, the solo dental practice comprises over 91 percent of the total. [3]

The typical private practice is normally composed of a dentist, one or two chairside assistants, a hygienist (full or part-time) and a receptionist. It is unusual for the practice to employ a dental laboratory technician. The number of operatories (chair bays) usually varies from one to four. In this environment a variety of dental treatment categories are performed. Typically these include: diagnostic, pedodontia, periodontia, prosthodontia, endodontia, orthodontia, oral surgery, preventive and restorative procedures. A later section of this chapter will present the approximate percentage of numbers of services delivered in each dental care area.

When a patient arrives for a scheduled appointment, he is either taken to an unoccupied operatory and seated or instructed to wait in the waiting room until an operatory is available. Once seated in the operatory, the chairside assistant prepares the patient for the scheduled treatment to be performed by the dentist or hygienist. After this preparation the patient waits until the appropriate person performs the scheduled treatment.

When he becomes available, the dentist, with the chairside assistant, performs the scheduled dental procedures on the patient. When the service is completed the dentist goes to another prepared and waiting patient while the chairside assistant dismisses the treated patient. This process repeats itself throughout the scheduled treatment period.

Description of the TEAM Dental Practice

The TEAM dental practice, as labeled by researchers in this field, will have many of the characteristics of the existing general practice. It is assumed that dental services will still be demanded of the TEAM practice with the same relative frequencies as in present dental practice, but will be delivered in a different functional arrangement.

In contrast to the dentist, the hygienist, and the chairside assistant of the contemporary dental practice, the proposed TEAM practice would employ a dentist, EFA's and chairside assistants. The EFA would be assisted by the chairside assistant on some procedures, while for others, the EFA will assist the dentist. For a number of procedures the dentist will be assisted by the chairside assistant as in contemporary practice. Thus, the TEAM practice introduces scheduling and interpersonnel dynamics substantially different from those in contemporary dental practice.

The proposed duties of the EFA would consist of a combination of "reversible" procedures now performed by the dentist and those tasks now performed by the hygienist. [13] The task of identifying dental procedures to be performed by the EFA has been widely discussed, but is to date unresolved. This is in large part due to the wide continuum of thought on the philosophy of EFA utilization and the scarcity of good research data. Another problem of EFA task identification is the legal constraint imposed by state dental practice acts when a person other than a dentist performs a semi-reversible procedure in a patient's mouth. In dealing with this problem, it was decided that the most commonly delegated procedures for the EFA in the literature and existing experimental and pilot programs would comprise the task inventory of the EFA in the model developed herein. [13, 19, 26] A listing of the tasks allocated to the EFA is presented later in this chapter.

In order to understand more clearly the dynamics of the proposed TEAM practice, a conceptual model is presented in Figure 1. Various dental practice factors which are a part of the simulated system are shown to interact as they occur in the model.

Methodology Experimental Design

There are several considerations which motivate an experimental design. In the development of this methodology, an experiment is needed which will predict probable dental team performance under a given set of decision variables. It is desirable to have a design which will allow an assessment of the changes that occur in the response (primary measure of effectiveness) as one or more factors are varied. Finally, an experiment is needed which will permit statistical comparison of indices of alternative dental team approaches to the delivery of dental services.

There are many possible measures of effectiveness that could be used for evaluation purposes when considering alternative dental resource configurations. Primary consideration will be given to one performance indicator, revenue derived by the dentist after expenses (net revenue), but before taxes. Traditionally, two other factors, utilization of dental personnel and patient waiting time, along with high quality health care delivery have been the most widely used criteria for assessing health systems performance. It is considered necessary to provide utilization data and patient delay statistics for consideration by the model user to aid in the choice of the most desirable dental team arrangement. Quality of dental services delivered will not be examined in this study as this has been extensively

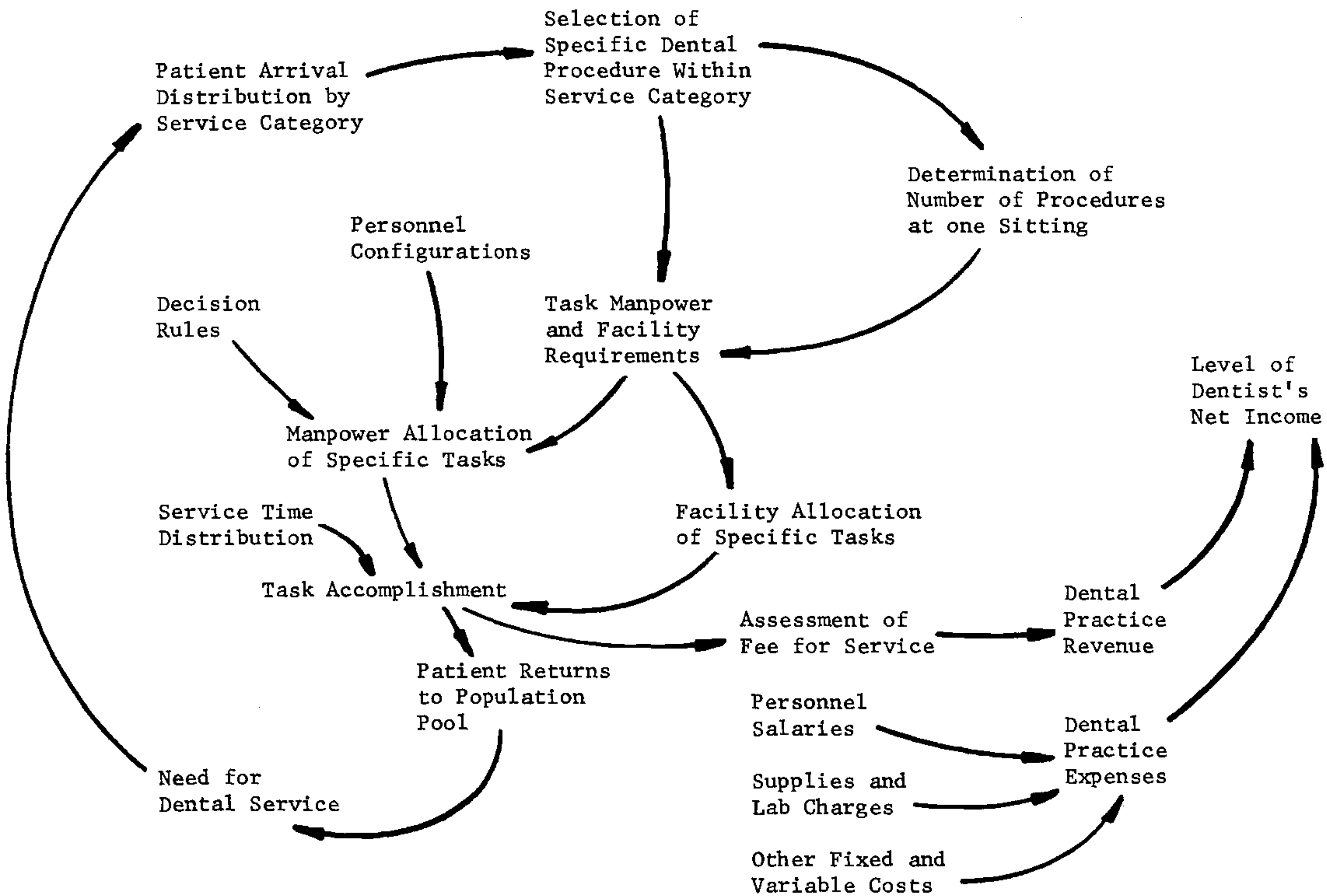

Figure 1. Conceptual Interaction of Modeled Dental Practice Factors.

examined in earlier work. [5, 12, 19, 26]

The underlying philosophy is that if the secondary measures of effectiveness (manpower utilization and patient delay) are within acceptable limits, then the decision maker can base his decision upon the primary measure of effectiveness (net revenue before taxes). In cases where the value of the secondary measures fall outside a reasonable range, some qualitative combination of all three of the measures of effectiveness <u>could</u> be devised to evaluate the performance of that configuration. However, since relative weighting of evaluation criteria is outside the scope of this study, the analysis will be based on the primary system response while providing data concerning other responses for subjective consideration by the decision maker.

Three system decision variables identified during the course of study were selected for variation in the model. These were the personnel configurations in the proposed practice (P), the number of operatories (O), and the decision rules exercised (D).

The personnel configurations, P, represent the numbers of EFA's and chairside assistants to be investigated by the simulation model. The model is capable of simulating a great variety of configurations. The guidelines for selecting the levels of P to be investigated are:

1. Only one dentist may be modeled. This restricts the methodology to solo dental practice, the predominant type of dental practice.

2. At least one EFA and one chairside assistant are required in each level of P.*

3. There is no upper limit on the numbers of EFA's and chairside assistants in each level of P.

The number of operatories, O, may be one or more. There is no upper limit on the number of operatories. The method for assessing the costs of the levels of P and O will be presented in the development of the cost model.

The factor D, the decision rule exercised was introduced to reflect the varying philosophies of use of ancillary personnel. Normally each ancillary personnel type has a defined skill level as a result of the dental tasks delegated to them. Thus, the more "skilled" an ancillary person, the more complex are the tasks delegated to him. Sets of dental tasks also could be defined according to the skill it takes to perform them adequately. The set of all dental tasks, say T, can only be performed by the dentist. The EFA is normally delegated a set of tasks, E, such that $\epsilon \subset E$. The chairside assistant is also delegated a certain set of tasks, C such that $C \subset E$ and $C \subset T$. A Venn diagram of this situation is presented in Figure 2.

It is clear that there are two alternatives by which dental practice personnel could provide services. These are:

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*At least one EFA is required to make the practice a TEAM environment and at least one chairside assistant is required to satisfy the requirements of four-handed dentistry.

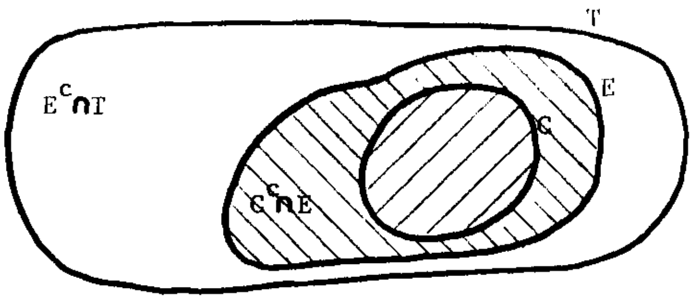

Figure 2. Venn Diagram of Dental Task Skill Sets

1. Each person may provide services only at his delegated skill level. Thus, the dentist would only provide those services contained in the set $E^c \cap T$ (all those tasks not contained in E but in T.) The EFA(s) would only provide the dental tasks contained in $C^c \cap E$ and the chairside assistant(s) would only perform those dental tasks in C.
2. Each person may provide services at his skill level <u>and</u> at any skill level below his. In this situation the dentist could perform all the tasks in T, the EFA all tasks contained in E, and the chairside assistant all tasks within C.

These are the two levels of D in the experiment.

An experimental design was needed which would investigate the effects of a number of different factors simultaneously. Also, an experimental design was needed to reflect factors being considered at fixed levels or values. Therefore, a fixed model, factorial experimental design was selected because it satisfied the two previously mentioned characteristics and it is highly amenable to analysis.

It should be noted that due to the interaction of the decision variables and the stochastic processes contained within the model, a measurable degree of variability could be expected from the same set of experimental conditions. Thus, it was decided that three observations would be taken under each of the experimental conditions. Each run simulates six months of system operation made up of 120 discrete seven hour days. This will be discussed in further detail in Chapter IV. In order to completely randomize the observations, a different random number seed was selected for each run.

The mathematical model for this experimental design is:

$$Y_{ijk\ell} = \mu + P_i + O_j + PO_{ij} + D_k + PD_{ik} + OD_{jk} + POD_{ijk} + \epsilon_{l(ijk)}$$

Where:

$Y_{ijk\ell}$	represents the response (net revenue generated under a given set of decision variables).
μ	represents the common effect for the experiment.
P_i	represents the personnel configurations in the system where $i = 1,2,\ldots m$.
O_j	represents the number of operatories in the system where $j = 1,2,\ldots.n$.
D_k	represents the decision rule employed in the system where $K = 1$ and 2.
$\epsilon_{l(ijk)}$	represents the random error in the experiment where $l = 1,2$, and 3.

The other terms represent the interactions among the factors P, O and D. A summary of the decision variables, the systems parameters, and the performance indices is presented in Figure 3. The definitions and derivation of the systems parameters follows in the next section of this chapter.

DECISION VARIABLES	SYSTEMS PARAMETERS		PERFORMANCE INDICES
Personnel Configurations	Service Frequency	Fee for Service	Net Revenue Before Taxes
Number of Operatories	Task Time Distributions	Cost Factors	Utilization of Dental Personnel
Decision Rules	Multiple Service Probabilities		In-Chair Patient Waiting Time
	Employee Break Time Distributions		Total Yearly Procedures Delivered

Figure 3. Decision Variables, Systems Parameters and Performance Indices of the Simulation Model.

It was recognized that development of a <u>totally</u> flexible methodology to investigate various solo dental practice factors was unnecessary. In order to achieve total flexibility the simulation model would have to be prohibitively large and unmanageable. Therefore, factors which would most likely be similar for most users of the methodology were built into the simulation model. A description of how these "built-in" parameters were developed is presented in the paragraphs below. The methodology application guide in Appendix C presents methods by which the built-in parameters and decision variables could be altered if desired.

Data Collection

Prerequisite to simulation model formulation and analysis is the collection of appropriate data as indicated by the nature of the experimental design. In a modeling endeavor which attempts to simulate a proposed system, subsystems of the modeled system may exist, but not in combination as they would appear in the proposed system. Nevertheless, to obtain data to describe elements of the proposed system, it is necessary to examine characteristics of existing or experimental subsystems. Several problems can arise in using this approach namely:

1. The subsystem analyzed may be highly dependent on operational characteristics unique to the existing system. Thus, the application of those data to an analogous system might be questionable.
2. The data gathered from an existing subsystem may not be suitable to fit unique situations found in the new system model.
3. There may be no existing subsystem that is an adequate analog of the operation of a portion of the new system.

It was assumed that the characteristic data collected from the various existing dental subsystems are compatible with the TEAM model and are valid for use in developing predictions about the TEAM dental practice. Four areas that required data collection for use in the model were identified:

1. A relative frequency distribution of major types of dental services performed in the typical private practice.
2. Probability distributions for dental procedure service times.

3. A distribution describing the probability that multiple services (two or more identical procedures) would be performed during a typical patient's visit.

4. A distribution which describes break time by employees during the day.

The following sections describe the data collection and analysis techniques employed in each of the above areas. The discussion of the cost evaluation parameters is presented in Chapter IV.

Distribution of Major Types of Dental Service

There were various sources of information from which to gather statistics for dental service distribution. However, some of these information sources were considered atypical of general dental practice. The two must useful sources of information for the TEAM model were the data compiled from the Louisville experiment [20] and statistics compiled from Dr. D. W. Heid's Washington State dental practice. The Heid practice, a general two-partner practice, provided the most complete information available for ascertaining dental service distributions.

Initially, percentage breakdowns for each dental service provided were calculated for the Heid practice. It was observed that a group of 28 of 184 listed services accounted for over 95 percent of the number of all services provided. It was assumed that this group of 28 dental services would adequately describe the typical distribution of dental service demand. The results of this analysis are given in Table 1.

Table 1. Distribution of Numbers of Dental Procedures Provided in the Heid Practice During 1970.

Model Code	Procedure Title	Total Number	Percent of Total Procedures
1	Initial Exam	641	13.7
2	Periodic Exam	931	19.8
3	Emergency Exam	106	2.3
4	Prophylaxis	480	10.3
5	Topical Fluoride	71	1.5
6	Mouth Guard	34	.7
7	Amalgam, 1 Surface	312	6.6
8	Amalgam, 2 Surfaces	604	12.9
9	Amalgam, 3+ Surfaces	254	5.4
10	Synthetic	341	7.2
11	Onlay	48	1.0
12	Porcelain Jacket	104	2.2
13	Gold Crown	125	2.7
14	Temporary Crown	42	.9
15	Recementation	30	.6
16	Endodontic Post	33	.7
17	Pulpotomy	10	.2
18	Root Canal	55	1.2
19	Gingivectomy	2	.1
20	Osseous Surgery	5	.1
21	Complete Denture	95	2.0
22	Gold Bridge	47	1.0
23	Denture Repair	10	.2
24	Extraction, Single	212	4.5
25	Extraction, Multiple	17	.4
26	Extraction, Surgical	28	.6
27	Orthodontic Applicance	7	.1
28	Emergency Treatment	47	1.0
	Diagnostic	1678	35.75
	Preventive	585	12.46
	Restorative	1894	40.35
	Endodontics	65	1.39
	Periodontics	7	.16
	Prosthodontics	152	3.25
	Oral Surgery	257	5.49
	Orthodontics	7	.15
	Other	47	1.00
	Total	4692	100.00

The data from the Heid practice were tabulated and compared with data from other sources of information giving percentage distributions for major dental services. The most recent available source of service distribution information was a study by Douglas [7] dealing with the effects on the dental service distribution of water fluoridation. Data obtained in the controlled Louisville experiment [20] were considered atypical when compared to statistics from a sampling of general dental practices.

Results of a goodness-of-fit test for Heid's practice data vis-à-vis the Douglas distribution are given in Table 2.

Table 2. Kolmogorov-Smirnov Goodness-of-Fit for Dental Service Distribution.

SERVICE	HEID FREQUENCY	(A) HEID CUMULATIVE FREQUENCY	(B) DOUGLAS CUMULATIVE FREQUENCY	|A-B|	MAX |A-B|	$D_{.95}$
Restorative	.4035	.4035	.4120	.0085		
Diagnostic	.3575	.7610	.7250	.0360		
Preventive	.1246	.8856	.8480	.0376	.0376	.04
Oral Surgery	.0549	.9405	.9260	.0145		
Other	.0100	.9505	.9370	.0135	∴	
Prosthodontics	.0325	.9830	.9820	.0010	cannot	
Periodontics	.0016	.9846	.9870	.0024	reject	
Orthodontics	.0015	.9861	.9900	.0039	the null	
Endodontics	.0139	1.0000	1.0000	.0000	hypothesis.	
	1.0000					

The results of Table 2 indicate that Heid's practice data are representative of general dental practice and hence are a reliable source of service frequencies for use in the simulation model.

Service Time Distribution Development

The most complete set of available service time duration distributions were compiled by Delaney [6] from the Louisville study statistics. However, these were presented as empirical distributions which presented modeling problems. The simulation model developed herein was run on the IBM 360 Model 30. This particular machine has limited capability for processing large simulations. Therefore, it was decided that theoretical distributions should be tested against the empirical distributions to reduce the volume of model parameters.

Various distributions were tested including beta, normal, rectangular, negative exponential, poisson, and gamma. The negative exponential distribution exhibited the best fit over all the types of service time distributions. In fact, for the large number of distributions tested for negative exponential goodness-of-fit, most of these tests were not significant at .05 percent α type error.

Dental task duration distributions describe the time required to deliver individual tasks within a specific procedure. In many cases the same person will perform two or more sequential tasks within a procedure without interruption. This situation coupled with the limited processing capacity of the computer being used to run the model resulted in the following simplifying procedure.

In an instance in which two sequential tasks were to be performed by the same individual, as an alternative to generating two service times, method was sought which would describe the length of both tasks with only one generated service time. This would reduce model size and machine running time substantially.

Negative exponential service times are generated in GPSS 360 by a multipicative combination of a mean service time and an exponential random variable. IBM supplies a continuous cumulative density function approximating the coordinates of exponential random variables (rnage zero to eight) and their probabilities of occurrence. Thus, random number generation yields an exponential random variable which in turn is multiplied by the mean service time μ to produce a service time from the exponential distribution with mean μ.

It was hypothesized that the service duration of two such generated exponential times with means μ_1 and μ_2 could be approximated with one exponential service time with mean μ_3, where μ_3 equals μ_1 plus μ_2. Theoretical proof of this hypothesis could not be found in the literature. However, investigation of the characteristic function for exponential distributions revealed an interesting result. It is known that the form of the resultant distribution of the sum of two random variables may be obtained by the multiplicative combination of the characteristic functions of the random variables [8].

The characteristic function, $\Phi(t)$, of the exponential distribution may be represented as:

$$\Phi(t) = \frac{\lambda}{\lambda - it}$$

where λ is the exponential parameter. Now define two independent exponential random variables with parameters λ_1 and λ_2 respectively. Performing the addition of independent random variables by the method of characteristic functions it is shown that

$$\left(\frac{\lambda_1}{\lambda_1 - it}\right)\left(\frac{\lambda_2}{\lambda_2 - it}\right) = \frac{\lambda_1 \lambda_2}{(\lambda_1 - it)(\lambda_2 - it)}$$

The right hand side of the above equation does not coincide with the characteristic function of a known probability distribution. Hence, it was decided that the form of the distribution resulting from the addition of two exponential random variables be investigated empirically. A FORTRAN IV program was written which generated the required distributions and performed a Kolmogorov-Smirnov difference for goodness-of-fit investigation. The program listing is contained in Appendix C.

The program generated 200 values from each of two exponential distributions with means of μ_1 and μ_2 respectively. The values were then summarized into 200 values by the operation

$$\sum_{i=1}^{200} x_{1i} + x_{2i}$$

where x_{1i} and x_{2i} represent the ith sample from the exponential distributions with means μ_1 and μ_2 respectively. Then, 200 samples from an exponential distribution with mean μ_3 were generated. Intervals of width 50 were established and individual samples from the two sets of samples were placed in appropriate intervals. The relative and cumulative frequencies of occurrence in the intervals was calculated for both samples. The maximum difference between the cumulative frequency of occurrence between corresponding intervals was the required Kolmogorov-Smirnov statistic.

For various values of μ_1 and μ_2 ranging from 200 to 1000, the hypothesis could not be rejected at the .01 α level for a two-tailed test. Therefore, this easily performed approximation enabled the model to run faster and require less memory.

The list of task mean times for the theoretical negative exponential distribution assumed in the model is presented in Table 3.

Derivation of Multiple Dental Procedure Probabilities

In the general dental practice, multiple services frequently are performed for a patient during a single visit. This phenomenon is particularly common with respect to restorative procedures, since patients who are treated for caries are likely to have more than one carious lesion requiring restoration. Since these restorative procedures are relatively quickly accomplished, it is common practice to perform multiple procedures at one sitting.

The only available source of information describing the frequencies of occurrence of multiple services during single visits were the data from the Heid practice referenced earlier. As was expected, multiple restorative procedures exhibited the highest frequency of occurrence. However, there were other services that had significant probabilities of multiple occurrences during single sittings. Table 4 lists the dental procedures that have significant probabilities (equal to or greater than .05) of multiple service delivery used in the model.

Employee Break Time Distribution

Standard operating procedure in a typical dental practice includes certain employee break time periods during the day. These might include morning coffee break, lunch, restroom break, and

Table 3. Mean Times for Exponential Task Duration Distributions.

Dental Task	Mean Time (Sec.)	Primarily Performed By Dentist	EFA	Chairside
Patient Preparation	204			X
Oral Exam	378	X		
Bitewing Radiograph	294		X	
Periapical Radiograph	294		X	
Local Anesthesia	198	X		
Rubber Dam	372		X	
Remove Temporary	150		X	
Tray Selection	318		X	
Alginate Impression	336		X	
Rubber Impression	252	X		
Stab. Rubber Impress.	541		X	
Oral Health Instr.	384		X	
Prophylaxis	600		X	
Topical Fluoride	600		X	
Mouth Guard	612	X		
Gingivectomy	4152	X		
Simple Amal. Prep.	228	X		
Compound Amal. Prep.	438	X		
Complex Amal. Prep.	660	X		
Matrix Placement	44		X	
Amalgam Placement	234		X	
Simple Amal. Carved	150		X	
Compound Amal. Carved	324		X	
Complex Amal. Carved	630		X	
Temporary Filling	330		X	
Amalgam Polished	198		X	
Synthetic Prep.	360	X		
Base for Synthetic	144		X	
Synthetic Placement	564		X	
Synthetic Finished	264		X	
Full Crown Prep.	982	X		
3/4 Crown Prep.	1260	X		
Jacket Prep.	974	X		
Dowel Prep.	2052	X		
Shade & Mould Sel.	216		X	
Temporary Crown	694		X	
Tryin of Bridge	1896	X		
Casting Adaptation	639	X		

Continued

Table 3. Mean Times for Exponential Task Duration Distributions. (Continuation)

Dental Task	Mean Time (Sec.)	Primarily Performed By Dentist	EFA	Chairside
Crown Cemented	733	X		
Bridge Cemented	2448	X		
Polish Crown	948		X	
Estab. Occ. Plane	894	X		
Bite Registration	1128		X	
Denture Pat. Instr.	360		X	
Denture Adjust.	636	X		
Tooth Extracted	144	X		
Impaction Removed	2850	X		
Suture Placement	336	X		
Exostosis Removed	3252	X		
Replace Crown	229	X		
Post Surg. Instr.	246		X	
Post Surg. Exam.	330	X		
Suture Removal	180		X	
Root Canal Drain	894	X		
Root Canal Enlar.	1994	X		
Root Canal Dress.	1062	X		
Fill Root Canal	1764	X		
Pulp Capping	1740	X		
Appliance Adjust	996	X		
Emergency	1728	X		

Table 4. Dental Services with Significant Conditional Probabilities of Multiple Occurrence at One Appointment.

PROCEDURE	PROBABILITY OF OCCURRENCE			
	NUMBER OF OCCURRENCES			
	1	2	3	4
Periapical Radiography	.46	.08	.31	.15
Amalgam, 1 Surf., Permanent	.65	.24	.04	.07
Amalgam, 2 Surf., Permanent	.45	.31	.13	.11
Amalgam, 3+ Surf., Permanent	.53	.28	.16	.03
Synthetic Restoration	.54	.19	.14	.13
Gold Crown	.95	.05		
Stainless Crown	.67	.33		
Gold Crown as Bridge Unit	.33	.67		
Extraction - Simple	.72	.26	.02	
Emergency Treatment	.83	.06	.11	

afternoon break.

These breaks are an important consideration when modeling a dynamic situation. In effect, each break causes a stop in patient flow, followed by a start up period. This situation causes substantial change in queue statistics when compared with the non-interrupted (no break) case.

In actual practice there is usually no predetermined time set aside for breaks other than the lunch hour. Usually breaks are taken when needed between dental tasks. These breaks include: restroom breaks, coffee breaks, telephone calls, discussions, consultation, supervision and other personal actions. In order to represent this situation in the model, a time distribution describing the length of time from the end of a procedure (or task) to the beginning of another procedure for an employee was developed.

Interviews with practicing and teaching dentists revealed that break durations between patients (or procedures) may range from a few seconds to five minutes. This was easily described with an exponential distribution with a mean of 60 seconds. This produces break durations from zero to 480 seconds utilizing the IBM exponential process generator.

CHAPTER IV

MODEL DEVELOPMENT

The development of the simulation model requires the synthesis of two model components, the cost model and the manpower/facility allocation and routing model. Both of these model components are described in this chapter. The general simulation model development and validation and verification also are presented. Also, identification of the post-simulation analysis techniques used in the methodology are presented.

In order to reduce repetition in the discussion of the methodology cost factors and the derivation of the methodology demonstration cost factors it was decided to present both the discussion and the derivation for the demonstration cost factors together. Methodology users can derive their cost factors in an analogous manner.

A user of the methodology developed herein might desire to investigate the consequences of a specific set of input factors, or desire to evaluate a broader spectrum of input factors and analyze the results. The methodology developed herein will allow either to be done. However, it is anticipated that the predominant use of the methodology will be by researchers investigating TEAM practice factors who in turn will report results to the dental community.

Cost Model Development

The response variable of the experimental design as previously discussed is net revenue derived under a given set of values of the decision variables. Net revenue is the difference between total or gross revenue and practice operating expenses. In order to use this cost evaluation scheme the various components of dental practice revenue and expense were described as they are used in the methodology along with the derivation of the demonstration figures.

Revenue Factor Development

It was assumed that all revenue derived by the general solo dental practice is generated by the collection of fees for dental services provided. Thus, to describe revenue generation one requires the actual fee schedule for dental services provided and a factor which indicates the ratio of fees collected to fees charged to patients. The latter factor was set at the national 1970 average of 97.8 percent [3].

The 1970 National Dental Fee Survey [2] was used as a basis for developing a fee schedule. However, not all the dental procedures included in the model were priced in this survey. A questionnaire was used to gather the missing procedure fees from a group of practicing and teaching dentists. The complete fee schedule used in the simulation model is presented in Table 5.

Expense Factor Development

Expense factor determination was more difficult to ascertain than revenue factors due to the many facets of dental practice overhead. A survey by the American Dental Association in 1970 indicates that over 48 percent of gross income in a typical dental practice goes to cover expenses for that practice [3]. Furthermore, four items

Table 5. Fee Schedule for Cost Model.

Procedure Code	Procedure Name	Average Fee To Patient
1	Initial Exam	5.00*
2	Periodic Exam	4.37
3	Emergency Exam	5.00*
4	Prophylaxis	9.74
5	Topical Fluoride	7.43
6	Mouth Guard	10.00*
7	Amalgam 1, Primary	7.83
8	Amalgam 2, Primary	12.51
9	Amalgam 3+, Primary	17.31
10	Synthetic Restoration	10.82
11	Gold Onlay	34.82
12	Porcelain Jacket	106.31
13	Gold Crown	90.65
14	Stainless Crown	25.78
15	Recementation	10.00*
16	Endodontic Post	30.00*
17	Pulp Cap	5.00*
18	Root Canal	66.47
19	Gingiv/Quad	49.52
20	Osseous Surgey	75.00*
21	Complete Denture	188.64
22	Bridge (3 Unit)	189.21
23	Denture Repair	20.48
24	Extraction, 1 Tooth	9.12
25	Extraction, Multiple	21.12
26	Surgical Impaction	49.05
27	Orthodontic Appliance	150.00*
28	Emergency Treatment	8.09

*The figures were obtained from a survey of practicing dentists. Other figures from 1970 National Fee Survey [2].

account for about 80 percent of this total expense percentage of gross income. These are: office rent and utilities, salaries, commercial dental laboratory charges, and expendable dental supplies.

If the cost model is to be sensitive to changes in personnel and facilities configurations, it must be based on expense (overhead) per procedure performed. This is required since changes in either manpower, facilities, or operating policies cause resulting changes in the number of procedures delivered. It is obvious, however, that some expenses are fixed (or proportional) for any configuration of resources. Thus, for a given resource configuration, two types of expenses may be identified; general operating costs and procedure-oriented costs. Below are listed the various cost components which are accounted for in the cost model.

General Operating Costs
- Personnel salaries
- Office rent and utilities
- Equipment purchases
- Depreciation of equipment
- Insurance premiums

Procedure-Oriented Costs
- Material and drug cost/procedure
- Laboratory charge/procedure
- Miscellaneous overhead/procedure

General Operating Costs. It was assumed that employees of the dental practice were salaried and not hourly wage earners. Although the literature widely varied on average salaries of dental personnel, it was suggested by most sources that 332 dollars a month for chair-side assistants and 500 dollars a month for EFA's was reasonable.

The 1970 ADA Dental Survey [3] gives a figure of 3523 dollars a year (293.58 dollars a month) as a national average for rent and utilities expenses to the dentist. Normally, office space is rented by the square foot with the average solo dental practice office being about 800 square feet (this figure was determined through interviews with practicing dentists). The Tufts survey [1] showed that the average dental office has 2.42 operatories. Also, the Tufts survey gave adequate data to calculate average operatory area size which computed to an average of 93.02 square feet. Multiplying this figure by the average number of operatories resulted in 225.1 square feet for the average total operatory area in the typical dental office. Hallway area associated with each operatory was assumed to be about 40 square feet or a total of 96.8 square feet of hallways for the average dental office.

Using the average rent and utilities expense per month and the average office area presented above, it was estimated that dental office floorspace rents for about 0.37 dollar per square foot per month. By using the national averages developed above, it was possible to develop average rent and utilities expenses for any number of operatories in the dental office. Table 6 presents these values for the numbers of operatories used in the demonstration.

Table 6. Average Rent and Utilities Expenses Incurred by the Dental Practice with Various Numbers of Operatories.

Number of Operatories	Total Operatory Square Footage	Total Office Square Footage	Dollars Per Month Rent & Utilities
2	268	747	276
3	403	882	326
4	536	1015	375
5	670	1149	435

About 40 percent of all dentists purchased dental equipment in 1970 [3]. The mean annual equipment expenditure for these dentists who purchased equipment was 1716 dollars. For the purpose of the demonstration described herein, it was assumed that some equipment would be purchased in implementing the TEAM concept. However, this equipment purchase would be proportional to the number of operatories. By utilizing the national average number of operatories in a typical dental practice (2.42) it was possible to develop a set of figures describing equipment purchases for varying numbers of operatories in a dental practice. The resulting calculations appear in Table 7.

Average annual equipment depreciation for the typical dentist in 1970 was 1180 dollars [3]. Since the research did not uncover statistics that would enable the depreciation of equipment to be converted to a depreciation rate, it was assumed that each configuration would have equipment depreciation proportional to the number of operatories. These figures appear in Table 7. The same was true for insurance related to the dental practice. No statistics could be found that adequately described the insurance rates on dental equipment, office, fire and theft, and other standard insurable properties. Thus, it was decided that the national average annual dental insurance cost of 546 dollars would be allocated proportionally over the total office square footage based on the average of 800 square feet. These results appear in Table 8.

Other overhead including laundry, office supplies, postage, office maintenance, and so on is related to volume of patients seen. The 1970 ADA survey [3] shows that an average of 2,982 dollars is

Table 7. Yearly Equipment Purchase and Equipment Depreciation Expenses for Various Numbers of Operatories.

Number of Operatories	Operatory* Ratio	Equipment Purchase Expenses Per Year	Equipment Depreciation Expense Per Year
2	.826	1,417	974
3	1.239	2,126	1,462
4	1.653	2,836	1,950
5	2.066	3,545	2,437

*This is the ratio of the various numbers of modeled operatories to the national average of 2.42 developed previously.

Table 8. Yearly Insurance Expenses for Various Numbers of Operatories.

Number of Operatories	Square Footage* Ratio	Insurance Expense Per Year
2	.934	509
3	1.102	601
4	1.269	692
5	1.436	784

*These figures are the ratio of the total square footage for offices with various numbers of operatories to the average 800 square foot office.

expended annually for such overhead. The same ADA survey also notes that the typical self-employed dentist averages about 3,428 patient visits a year. Hence, it was assumed that the ratio of these statistics (0.87 dollars per patient visit) will suitably represent the average fixed overhead per patient visit without regard to procedure type.

Procedure-Oriented Costs. It was felt that the materials and supplies cost per procedure would vary substantially among different dental procedures performed. However, the literature revealed no usable statistics for the calculation of this procedure cost.

In order to calculate these per procedure costs, two types of information were collected from a panel of practicing dentists at the Medical College of Georgia. These were the unit costs of all frequestly used materials and supplies and the amount of each supply or dental material used in each procedure. The result of this survey is presented in Table 9. Several local dental laboratories were surveyed to obtain laboratory charges incurred by the dentist for various procedures which require commercial laboratory assistance. A summary of both supplies and materials cost and laboratory costs per procedure is presented in Table 9.

Table 9. Material/Supplies and Laboratory Expenses to the Practice Per Procedure.

Procedure Code	Procedure	Materials & Supplies Cost	Laboratory Charge
1	Initial Exam	1.68	
2	Periodic Exam	.30	
3	Emergency Exam	.14	
4	Prophylaxis	.61	
5	Topical Fluoride	.80	
6	Mouth Guard Delivery	.66	5.00
7	Amalgam 1, Primary	.57	
8	Amalgam 2, Primary	.85	
9	Amalgam 3+, Primary	1.27	
10	Synthetic Restoration	1.93	
11	Gold Onlay	1.32	18.00
12	Porcelain Jacket	1.32	22.00
13	Gold Crown	1.32	18.00
14	Stainless Crown	.78	
15	Recementation	.46	
16	Endodontic Post	1.32	
17	Pulp Cap	.61	
18	Root Canal	.76	

(Continued)

Table 9. Material/Supplies and Laboratory Expenses to the Practice Per Procedure. (Continued)

Procedure Code	Procedure	Materials & Supplies Cost	Laboratory Charge
19	Gingiv/Quad	.76	
20	Osseous Surgery	.76	
21	Complete Denture	1.55	120.00
22	Bridge (3 Unit)	1.32	18.00
23	Denture Repair	.72	
24	Extraction, 1	.36	
25	Extraction, Multiple	.51	
26	Surgical Extraction	.36	
27	Orthodontic Appliance	.53	15.00
28	Emergency Treatment	2.00	

A summary of the cost model components is presented in Table 10.

Table 10. Summary of Cost Model Components.

Cost Components	Symbol	Demonstration Value
Fee Scale	F_i	See Table 5
Personnel Salaries	S_j, S_k	332/500 dollars/month
Rent and Utilities	R_i	See Table 6
Equipment Purchase	EP	See Table 7
Equipment Depreciation	ED	See Table 7
Practice Insurance	I	See Table 8
Miscellaneous Overhead	O	0.87 dollars/patient visit
Materials and Supplies	MS_i	See Table 9
Laboratory Charge	L_i	See Table 9
Collection Ratio	η	97.8%
Procedures Performed	P_i	-

The cost model can be represented symbolically as:

Net Revenue = Gross Revenue - Expenses

$$= \eta \sum F_i - [\sum S_j + \sum S_k + R_i + EP$$

$$+ ED + I + \sum OP_i + \sum MS_i P_i + \sum L_i P_i]$$

It should be reiterated that users of the methodology consult the application guide in Appendix C which describes the formulation of user input data and the amendments to the simulation model.

Manpower/Facility Allocation and Routing Model Development

The next phase of the simulation model development was the construction of a resource allocation and routing model. This general model component performs various functions which imitate the operation of a typical dental practice. These include:

1. Patient arrival generation
2. Dental procedure determination
3. Number of dental procedures or tasks performed per patient
4. Operatory assignment
5. Dental personnel assignment; skill levels
6. Dental personnel break times
7. In-service patient waiting time.

Probability distributions for some of these functions were derived in Chapter III. This section will discuss all of the above functions in terms of their operational characteristics in the simulation model.

Patient Arrival Generation

It is standard policy in most dental practices to schedule patients for dental appointments at specific times during the working day. This gives the dentist the prerogative of scheduling certain types of services during preferred times of the day. However, some overlap among patients is usually scheduled to make allowance for patients who might have short service time durations. This overlap gives the effect of a patient always being available when one of the practice staff becomes free.

It was assumed that the service distribution probabilities developed previously would approximate, in the long run, the number of patients in each service category seen by the dentist in a typical year. Also, it was assumed that the generation of a patient every time a patient is dismissed will adequately mimic the scheduled overlap scheme used by most dentists. This latter assumption will result in the maximum patient flow rate achievable for a given configuration of decision variables.

Dental Procedure Determination

Once resources become available, a patient is generated and routed for a specific dental procedure included in the model. This routing is accomplished using the procedure relative frequency statistics developed in Chapter III, Table 1.

Dental Procedures Per Patient Sitting

Certain dental procedures, predominantly restorative, have significant probabilities of multiple occurrence for a patient at a single sitting. These conditional probabilities were developed in Chapter III, Table 4. When instances occur in the model where procedures (that have multiple occurrence probabilities) are assigned to a patient, the model selects via random number generation (Monte Carlo Simulation) the number of procedure occurrences to be accomplished at that sitting.

Operatory Assignment

It was noted previously that a new patient is available for service immediately upon dismissal of a patient who has completed service. The practice "waiting room" in the demonstration is modeled by a GPSS entity, termed a storage, with maximum capacity of five. This means that up to five generated patients may be awaiting assignment to an operatory for service initiation. This virtually assures that a patient is always available to occupy a vacated operatory.

Some dentists dedicate certain specially equipped operatories for a particular type of service or procedure. The philosophy of TEAM practice indicates, however, that this type of operatory dedication loses effectiveness due to the interchangibility of personnel performing dental services. Therefore, in the simulation model no attempt was made to reserve operatories for particular services or procedures.

Dental Personnel Assignment

Personnel assignment to perform dental tasks is the most significant difference between the modeled TEAM practice and the typical dental practice. It is through the judicious use of auxiliary personnel that substantial gains are expected to result from implementing TEAM concepts.

The assignment of dental personnel for task performance under decision rule one, an experimental design factor, dictates that only a designated dental personnel type may perform a specific task when that task occurs in a dental procedure. These primary skill inventories of the practice personnel were presented in Chapter III, Table 3.

Decision rule two required the establishment of a set of logical guidelines for substitution of dental personnel assignment in the situation where the primary task performer was busy. These guidelines for personnel substitution were:

1. The dentist could not be replaced for any task which was included in his primary skill inventory.
2. The EFA could be replaced by the dentist for a task in the EFA primary skill inventory in an instance where the EFA was busy.
3. Only "upward" assisting would be allowed. That is, the primary task performer could only be assisted by a person with a skill inventory lower than theirs. Thus, this eliminates an EFA assisting an EFA. This assumption of upward assisting seems consistent with the principles of DAU and TEAM.

Prior to any substitution of personnel as described above, the primary performer of a dental task was monitored to ascertain his availability to perform the task. Only if all of the personnel assigned that task in their primary skill inventory were busy, was substitution of a higher personnel type attempted. If all available personnel with skill inventories to perform a task were busy at the time that task was required, the primary personnel were always checked first at a later time.

Dental Personnel Break Times

As described earlier in Chapter III, the simulation of personnel break times was an important contribution to the dynamics of the

TEAM model. When dental personnel complete their assigned task(s) on a patient, they will typically be delayed (simulating a break or time to scrub before another dental task) prior to initiation of a task on a different patient.

Lunch time breaks for employees were set at one hour (12:00 to 1:00) at which time in-chair patients were dismissed (typically unfinished) from the practice. Since, at most, five unfinished patients could be dismissed at this lunch time break and since each simulation run did likewise, this procedure allowed comparison among model configuration responses. After the lunch break patient and practice personnel dynamics resumed as normal.

In-Service Patient Waiting Time

Statistics concerning patient waiting time while seated in the operatory were gathered via a GPSS entity termed a queue. This entity automatically collects delay information for use in assessing the effectiveness of a combination of levels of experimental factors.

When the patient was available for service to begin, that patient was placed in a waiting state (enter queue). Upon initiation of service the patient was removed from this waiting status (depart queue) and remained in active status until service was interrupted or complete. If service was interrupted, the patient was once more entered in the queue.

General Model Development

The resource allocation and routing model was conceptualized in a flow chart of the various operations involved in the TEAM practice model. The flow chart was used as a basis for the integration of the cost model into the general simulation model.

The simulation model was then coded in GPSS 360 for verification and validation on the IBM 360 Model 30. A listing of the general model program is presented in Appendix A.

Verification and Validation

Naylor, et al, [23] suggest that verification of simulation models is perhaps the most elusive of all the unresolved problems associated with computer simulation techniques. To verify or validate any kind of model means to establish that the model represents truly what it was designed to represent. Yet, the definition of "true" suggests that a set of criteria are available for comparison of reality with the model results. Such a set of criteria does not exist at present.

Mihram [21] has delineated the definitions of verification and validation of simulation models and offers means to test the model for each. His definitions of these confirmation techniques and the results of their applications to the model developed herein are presented in the following paragraphs.

Verification

Mihram's definition of verification, "the determination of the rectitude of the completed model vis-á-vis its intended algorithmic structure," calls for investigation of syntactical and semantic errors followed by determination of a specific set of conditions for which the model's response could be predicted, provided that the model is programmed in accordance with the modeler's intentions.

Initially, the newly-fabricated model was desk-checked for semantic and syntactical errors. This operation has heretofore been termed "debugging." After these checks were performed, the model logic was then desk checked to ascertain the accuracy of the intended algorithmic structure of the model operation.

For the verification procedures, methods for collection of detailed statistics were included in the model for this purpose. Using the cost and routing parameters previously identified, the model was run for a simulated period of one month. By using the detailed statistics for numbers and types of procedures delivered, it was possible to calculate by hand the projected cost and patient volume and frequency figures for that simulated time period. This calculated projection did indeed reflect the actual output for the simulated period. It was, therefore, assumed that verification of the simulation model was complete and that validation procedures could be performed.

<u>Validation</u>

The definition of validation given by Mihram, "the comparison of responses emanating from the verified model with available information regarding the corresponding behavior of the simulated system," calls for testing the model's output against known results. This comparison presented problems. Since no real private practice data were available for TEAM dental processes, a direct comparison of this type was impossible. It was assumed, however, that if the model adequately mimicked a typical practice which consisted of a dentist and various levels of chairside assistants and operatories, then the model's operation would accurately predict the outcome of inclusion of EFA's in the modeled practice.

Actual comparison data were readily available in the 1971 Survey of Dental Practice [3]. The model simulated with various levels of chairside assistants and operatories was compared with corresponding levels compiled in the survey. Factors such as net income, numbers of patients seen, personnel utilization and patient waiting time were investigated and sources of discrepancy adjusted in the model. It was found that the model was flexible enough to predict the actual practice factors over a wide range of levels of input factors. Thus, it was concluded that the simulation model could adequately predict the outcome for the variety of input factors to be investigated in the experimental design.

Post-Simulation Analysis Techniques

The state-of-the-art of computer simulation output analysis has not progressed as rapidly as the techniques of modeling and simulation. Particularly, there is a seeming lack of availability of practical applications of optimization techniques for analyzing simulated economic system with multiple decision variables. Some techniques that could be adapted as an optimization tool include: regression techniques, differential calculus, response surface methodologies, multiple range and comparison techniques, multiple ranking methods, and sequential sampling methods.

Analysis of variance (ANOVA) and a multiple range technique are used in the methodology for the analysis of the data generated by the simulation model developed previously. A brief discussion of the reasons these techniques were chosen is presented along with the application of the techniques in Chapter V.

CHAPTER V

METHODOLOGY DEMONSTRATION

This chapter presents the results of a demonstration of the methodology using national average dental practice data and conservative conventions, and a discussion of the implications or various resource configurations for solo TEAM practice.

The methods of analysis used to examine the demonstration results are representative of the types of techniques that are available to the analyst. However, it is clear that the selection of specific analysis techniques should fit the needs of the user. Obviously, simulation of a particular personnel configuration, a certain number of operatories, or a specific fee scale would yield only one set of output data and a minimum of analysis would be required. Alternatively, if more levels of decision variables and/or input parameters are to be simulated, techniques similar to the ones described in this chapter would be called for. Following, is a discussion of an illustrative application of the methodology developed in previous chapters. The systems parameters developed previously were used as inputs to the simulation model. The experimental design described earlier was followed in the course of the model simulation. The levels of factors used in the illustrative application of the methodology are presented in the paragraphs below.

Methodology Demonstration Description

The factor levels for the demonstration experimental design were derived as follows. The personnel configurations were subjectively determined. Past experimental studies dealing with EFA allocation in a dental facility have arrived at a ratio of about three or four auxiliaries to one dentist for near optimum performance [19]. Practicing dentists interviewed in and associated with the School of Dentistry at the Medical College of Georgia agree that if the number of auxiliary personnel is greater than four per dentist then it is extremely difficult to utilize these personnel efficiently. Thus, it was decided that simulated combinations of auxiliaries (EFA's and chairside assistants) and dentists should not exceed a ratio of more than four auxiliaries to one dentist and that at least one of each type of auxiliary be present in each configuration. Below are listed the seven levels of personnel configurations P simulated in the demonstration.

PERSONNEL CONFIGURATION NUMBER	NUMBER OF DENTISTS	NUMBER OF EFA'S	NUMBER OF CHAIRSIDES
1	1	1	1
2	1	1	2
3	1	1	3
4	1	2	1
5	1	2	2
6	1	3	1
7	1	4	1

It should be noted that personnel configuration 7 exceeds the ratio previously stated as a rule for allocation. It was, however, an attempt to discover marginal changes in total production of the practice contributed solely by the EFA.

Four levels of O (two, three, four and five) were determined subjectively, but are suggested as being reasonable in the literature and by dental educators. Two levels of D previously described in Chapter III were considered. These two decision rules are a reflection of differing points of view by the dental profession as to the proper use of ancillary personnel.

Analysis of Variance

ANOVA does not directly offer a means for discovery of the optimum combination of levels of experimental design factors. However, ANOVA does give insights pertaining to the interaction among the decision variables. The general hypothesis tested was that there are significant main effects and interaction effects among all of the independent variables with respect to the dependent variable. The hypothesis was tested by advancing the null hypothesis that there are no significant main effects and no interaction among the variables.

A factorial experimental design was developed using procedures defined by H. O. Hartley [14]. Assumptions were made of homogeneity of variance, normality of group means, and additivity of effects. A four-way ANOVA was conducted for the primary measure of effectiveness data shown in Table 11. The mathematical model for the experimental design was presented in Chapter III. The ANOVA results are summarized in Table 12. Since the levels of each factor in the model were fixed, the tests for significance were straight-forward. All tests were made by using the error mean square in the denominator of the F-test.

Table 11. Simulated Net Income Derived by Dentist.

	2 Operatories		3 Operatories		4 Operatories		5 Operatories	
	Rule 1	Rule 2	Rule 1	Rule 2	Rule 1	Rule 2	Rule 1	Rule 2
1 EFA; 1 CSIDE	8,801	16,234	10,085	14,433	9,134	13,622	11,042	12,561
	9,127	16,675	8,537	16,666	7,065	12,314	9,580	13,612
	11,888	17,610	10,548	14,655	10,445	15,611	11,602	13,883
1 EFA; 2 CSIDE	15,501	27,309	13,836	26,553	18,098	26,146	20,426	22,618
	15,496	24,299	14,700	19,653	19,437	24,313	21,714	23,737
	16,272	30,205	16,458	26,330	19,423	21,952	22,064	21,688
1 EFA; 3 CSIDE	9,789	28,848	15,584	27,535	15,965	27,655	17,168	26,661
	11,517	23,906	12,012	28,676	14,976	24,549	14,302	22,988
	12,288	26,112	14,009	26,330	13,656	28,093	14,914	27,362
2 EFA; 1 CSIDE	8,016	16,593	9,952	17,320	5,086	17,251	6,931	14,361
	9,216	17,192	4,000	16,378	6,001	16,816	5,325	14,137
	8,634	16,521	7,578	15,534	6,049	16,652	2,680	12,979
2 EFA; 2 CSIDE	21,667	28,301	25,274	25,893	22,382	26,911	23,211	25,800
	20,638	22,814	24,303	22,738	19,837	22,994	21,699	24,302
	22,956	27,644	24,368	23,790	25,251	27,398	22,076	26,542
3 EFA; 1 CSIDE	2,701	10,962	- 280	15,172	1,261	13,404	-1,982	14,940
	3,258	11,118	- 994	17,414	-1,003	13,155	-2,998	9,877
	3,022	12,507	1,918	14,509	725	15,435	-2,483	14,046
4 EFA; 1 CSIDE	-2,161	4,962	-4,370	13,326	-6,484	13,947	-6,581	12,178
	-2,715	5,118	-7,432	12,378	-6,785	14,580	-9,978	9,467
	-3,111	6,507	-4,081	9,042	-4,958	11,573	-8,546	8,976

Table 12. ANOVA for Simulated Dentist's Net Income.

Source	SS	df	MS	F	$F_{.01}$	$F_{.05}$	
O	19,704,864	3	6,568,288	2.41	3.95	2.68	
D	3,667,790,848	1	3,667,790,848	1,348.04	6.85	3.92	**
OD	13,754,035	3	4,584,678	1.68	3.95	2.68	
P	9,343,934,464	6	1,557,332,240	572.37	2.96	2.17	**
OP	121,732,736	18	6,762,929	2.49	2.03	1.66	**
DP	828,217,600	6	138,036,256	50.73	2.96	2.17	**
ODP	308,551,424	18	17,141,744	6.30	2.03	1.66	**
Error	304,732,505	112	2,720,826				
Total	14,608,392,192	167					

**Significance at the 1% level.

More detailed information about the techniques employed in the ANOVA may be found in Hicks [16].

The results of the ANOVA show a significant decision rule effect, D. A main effect, O, and the OD interaction were not found to be significant. However, the other main effects interactions were significant. It can be concluded from these results that a significant gain in net income can be achieved by adopting the second decision rule. It can also be concluded that there are real variations in the net income due to the main effects D and P and in all interactions except OD.

The highly significant main effects D and P and their interaction DP were investigated graphically to gain some insight into the cause of variation. The seven displays of Figure 4 show the response as a function of the number of operatories O, with D and P held constant. The curves labeled D_1 and D_2 represent, respectively, the two decision rules employed.

The gaps between the curves in each set illustrate the size of the decision rule effect. In all cases D_2 dominated D_1 (greater net income). Therefore, it was decided to perform a further ANOVA on the D_2 responses to see if P remained significant and if O was still not significant.

The mathematical model for the second experimental design was:

$$Y_{ijk} = \mu + P_k + O_j + PO_{ij} + \epsilon_{k(ij)}$$

where:

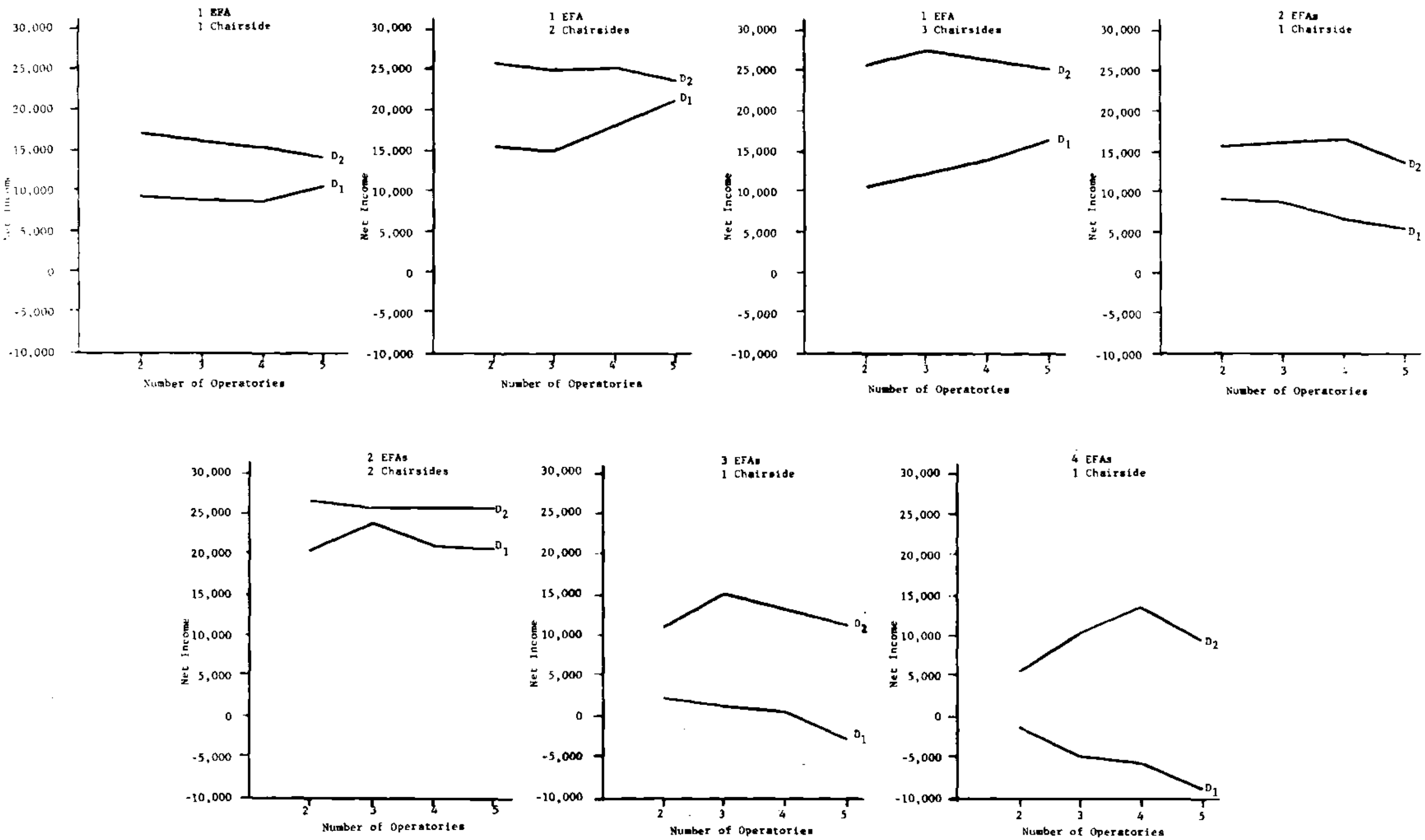

Figure 4. Net Income for Various Personnel Configurations

Y_{ijk} represents the response (net income)

μ represents the common effect for the experiment

P_i represents the personnel configurations in the system where i=1, 2, ..., 7

O_j represents the number of operatories in the system where j=2, 3, 4, and 5

$\epsilon_{k(ij)}$ represents the random error in the experiment where k = 1, 2, and 3.

The results of the second ANOVA are presented in Table 13. Once again there was significant personnel configuration main effect P. The OP interaction was also significant. However, the main effect O, the number of operatories, was not significant at the one percent level. To gain insight into the OP interaction the responses for the seven levels of P were plotted against the number of operatories. This plot is presented in Figure 5.

Multiple Range Test

Since the main effect O in both of the previous ANOVA's was not significant at the one percent level, it was decided to perform a Duncan's Multiple Range Test [16] since this is an appropriate technique for comparison of means after experimentation for fixed factors. Values of O were pooled to determine if there were significant differences among the seven mean values of P.

First, the four O responses for each level of P in D_2 were pooled to form mean values of:

Table 13. ANOVA for Simulated Dentists' Net Income Under D_2.

Source	SS	df	MS	F	$F_{.01}$	$F_{.05}$	
O	30,621,216	3	10,207,072	2.941	4.13	2.76	*
P	3,137,774,336	6	522,962,176	150.673	3.12	2.25	**
OP	183,766,336	18	10,209,240	2.941	2.20	1.75	**
Error	194,366,536	56	3,470,831				
Total	3,546,528,000	83					

*Significance at the 5% level.

**Significance at the 1% level.

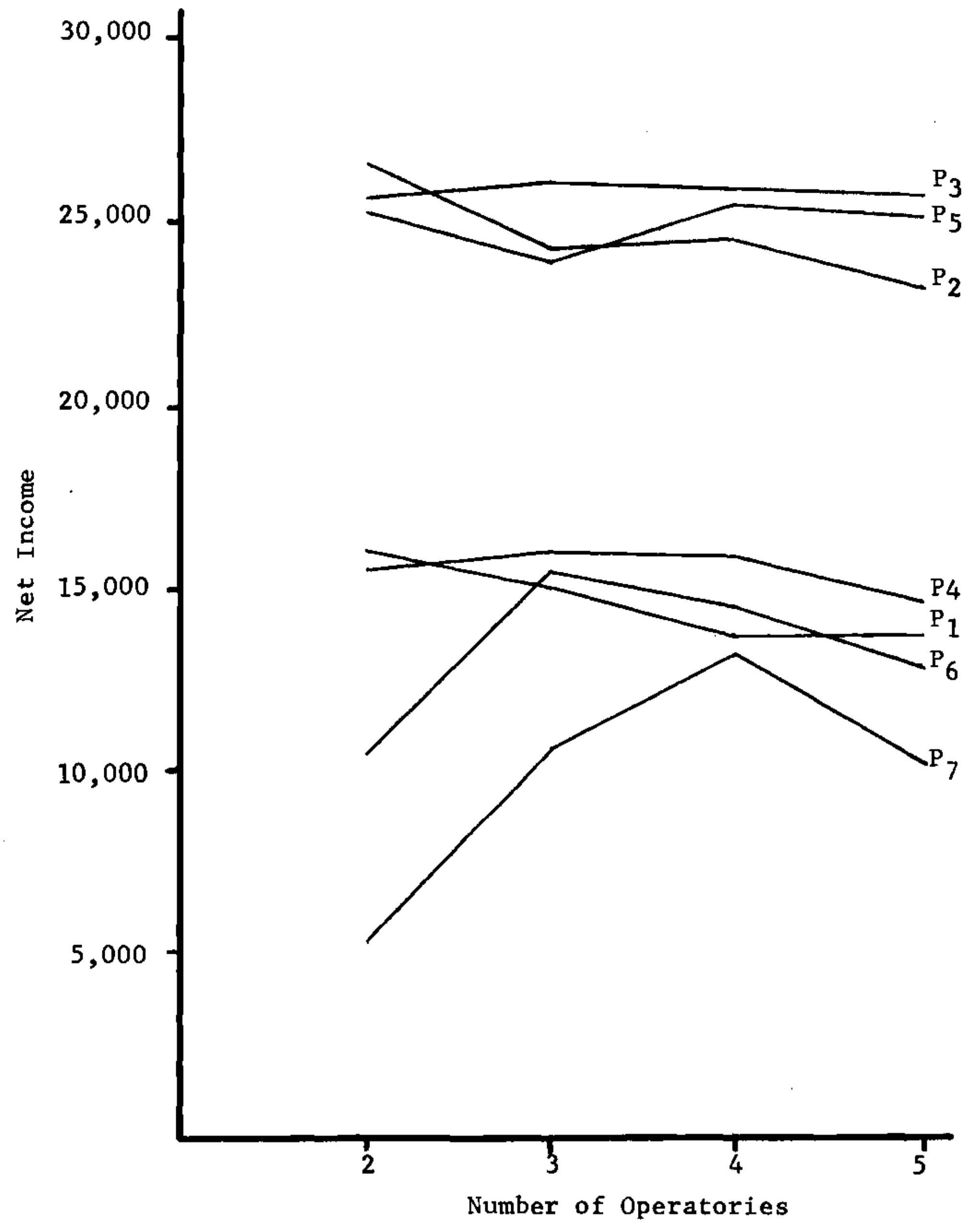

Figure 5. Net Income for Various Factor Levels Under D_2

	$\bar{X}$
P_1	14,823
P_2	24,567
P_3	26,449
P_4	15,978
P_5	25,427
P_6	13,545
P_7	10,171

where $\bar{X}$ denotes the mean value of the pooled O responses. The error mean square from Table 13 was 3,470,831 with 56 degrees of freedom. The standard error for the mean $s_{\bar{x}}$ was calculated as:

$$s_{\bar{x}} = \sqrt{\frac{3,470,831}{4}} = 931.5$$

where the denominator is the number of observations pooled in P. Setting the significance level at $\alpha = .05$ the Duncan's significant studentized ranges for 56 degrees of freedom are:

R =	2	3	4	5	6	7
Studentized Ranges =	2.83	2.98	3.08	3.14	3.20	3.24

where R represents the range of comparison between two ordered means. The least significant ranges (LSR) were obtained by multiplying each of the above studentized ranges by $s_{\bar{x}}$. The LSR's for the mean comparisons were:

R =	2	3	4	5	6	7
LSR =	2,636	2,776	2,869	2,925	2,981	3,018

Each mean was then compared with every other mean; the differences between means were then compared with the appropriate LSR. The results of these comparisons are given in Table 14.

There were significant differences among three groups of means P_7 and P_6, P_1, P_4 and P_2, P_5, P_3. Within each group, however, there were no significant differences and these means could therefore have come from a common population. The results of the Duncan's Multiple Range Test are presented graphically in Figure 6.

Figure 6. Results of Duncan's Multiple Range Test.

Discussion of Demonstration Results

The statistical methods employed to this point have identified three treatment combinations within decision rule two as being dominant over all others. Yet, the three treatment combinations, P_2, P_5, P_3, are not significantly different from each other.

On the surface, one might expect that P_4 (2 EFA's and 1 chairside) would yield a response comparable to that of P_2 (1 EFA and 2 chairsides) due to the EFA's ability to perform chairside duties. And, for the personnel configurations simulated, one might expect that personnel configurations with <u>equal totals</u> of ancillary personnel would yield <u>equal responses</u> for the second decision rule. This conclusion is shown to be invalid due to several considerations.

The salaries of the two ancillary personnel types are not

Table 14. LSR Comparisons for Pooled P Responses.

Comparison	Observed Difference	Least Significant Range	Significance
7 vs. 3	16,278	3,018	*
7 vs. 5	15,256	2,981	*
7 vs. 2	14,396	2,925	*
7 vs. 4	5,807	2,869	*
7 vs. 1	4,652	2,776	*
7 vs. 6	3,374	2,636	*
6 vs. 3	12,904	2,981	*
6 vs. 5	11,882	2,925	*
6 vs. 2	11,022	2,869	*
6 vs. 4	2,433	2,776	
6 vs. 1	1,278	2,636	
1 vs. 3	11,626	2,925	*
1 vs. 5	10,604	2,869	*
1 vs. 2	9,744	2,776	*
1 vs. 4	1,155	2,636	
4 vs. 3	10,471	2,869	*
4 vs. 5	9,449	2,776	*
4 vs. 2	8,589	2,636	*
2 vs. 3	1,822	2,776	
2 vs. 5	860	2,636	
5 vs. 3	1,022	2,636	

*Significant at = .05

equal. The EFA's salary is 50 percent greater than that of the chairside assistant. An EFA performing a chairside assistant duty causes the unit cost of the procedure to increase, thus increasing practice overhead and reducing net income.

For the personnel skill inventories simulated, the actions of each personnel type visualized at any time interval gives understanding of the interpersonnel dynamics that occur. Figure 7 presents Multi-Man charts of the activities of each dental practice person, specifically for both P_2 and P_4 with two operatories. The procedures occurring in operatory one are a two surface amalgam restoration and the start of a gold crown, while in operatory two a simple extraction, an oral exam, and a prophylaxis are performed. Further, assume that D_2 is in effect and the amalgam restoration in operatory is in progress.

Examination of the charts for P_2 and P_4 reveals that there are substantial differences in the interpersonnel activities that occur during the performance of various dental procedures. The chart does not account for the variable break time possible at the end of each task that the practice personnel take in the simulation model. But even simplified by this, the charts do indicate the difficulties that arise resulting from simultaneously obtaining a primary task performer and an assistant for most of the tasks performed when either the assistant or primary task performer are not immediately available. This is particularly evident in P_4 where there is only one chairside assistant.

The chart for P_4 reveals that most of EFA2's time is spent

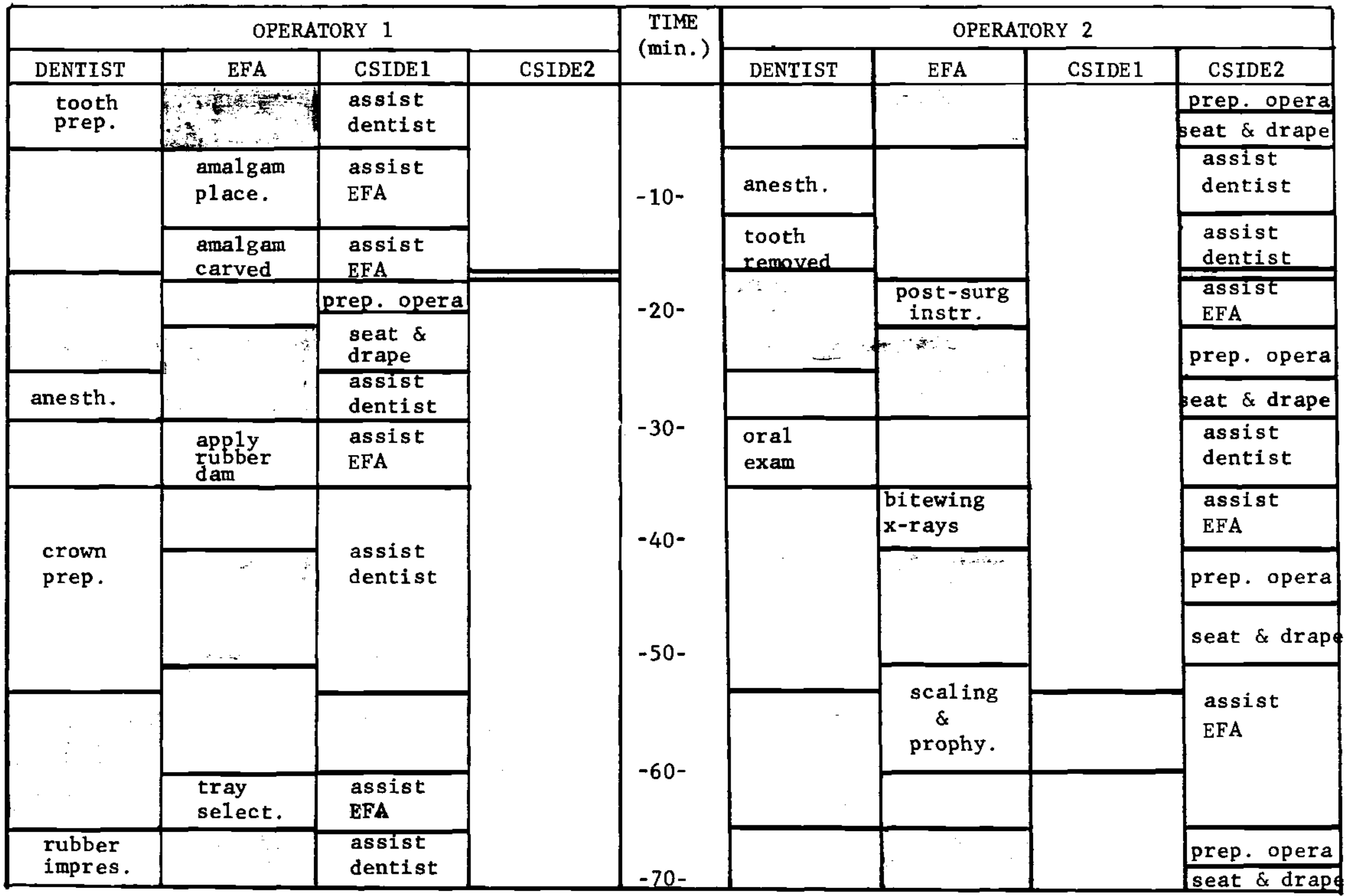

Figure 7. Dental Procedure Multi-Man Chart for P_2

OPERATORY 1				TIME (min.)	OPERATORY 2			
DENTIST	EFA1	EFA2	CSIDE		DENTIST	EFA1	EFA2	CSIDE
tooth prep.			assist dentist				prep.opera.	
							seat & drape	
	amalgam placemt.		assist EFA	10	anesth.		assist dentist	
	amalgam carved		assist EFA		tooth removed		assist dentist	
			prep. opera	20	post-surg instr.		assist dentist	
			seat & drape				prep. opera.	
anesth.			assist dentist				seat & drape	
	rubber dam		assist EFA	30	oral exam		assist dentist	
crown prep.			assist dentist	40 50				
							bitewing x-rays	assist EFA
	tray select.		assist EFA	60			prep. opera.	
rubber impress.	assist dentist							seat & drape
				70			scale & prophy.	assist EFA

Figure 7. Continued (for P_4)

assisting the dentist and doing non-revenue producing tasks. Also, EFA1 in P_4 is utilized very little even though most of that work is revenue producing. A comparison of the charts for P_2 and P_4 shows that more revenue producing work is accomplished under P_2 and that the work is spread more evenly throughout the practice personnel. Further, the decision rule does not allow an EFA to assist another EFA. This can cause two idle EFAs to remain idle. If, on the other hand, an EFA and a chairside assist were available work could be accomplished because this pair satisfies the four-handed dentistry constraint.

Thus, it appears that the higher unit costs associated with EFA's performing non-renue producing work (assisting), the complex interpersonnel dynamics involved with more EFA's than chairside assistants, and the rapidly increasing amount of EFA non-revenue generating work caused by unavailable chairside assistants cause a resultant effect which is manifested in low net income. Still, due to the personnel flexibility for task delivery in D_2, the responses for D_2 are significantly greater for corresponding levels of P in D_1.

An examination of the yearly total number of procedures delivered, one of the secondary measures of systems effectiveness, supports the considerations described above. Table 15 presents yearly total numbers of procedures delivered in the simulated practice.

The ANOVA summarized in Table 16 with yearly procedures delivered as the response shows that there is a significant difference between responses for D_1 and D_2, with D_2 having greater numbers

Table 15. Number of Procedures Delivered Yearly.

		D_1				D_2			
		O_1	O_2	O_3	O_4	O_1	O_2	O_3	O_4
R_1	P_1	2359	2332	2553	2736	2937	2856	2996	2933
	P_2	3073	3217	3720	4241	3935	4273	4222	4366
	P_3	2866	3509	3981	4214	4594	4836	4841	4870
	P_4	2752	2691	2726	2834	3511	3463	3818	3628
	P_5	4302	4556	4458	4790	4453	4827	4963	4755
	P_6	2691	2736	2816	2742	3408	4023	3979	4158
	P_7	2741	2715	2823	2823	3405	4074	4371	4449
R_2	P_1	2585	2470	2537	2773	2834	2850	2967	2899
	P_2	3137	3424	3758	4034	4015	4165	4021	4276
	P_3	3073	3471	3731	4138	4491	4751	4825	4824
	P_4	2813	2702	2813	2641	3594	3474	3562	3460
	P_5	4132	4469	4450	4686	4376	4660	4982	5029
	P_6	2768	2752	2930	2839	3615	4039	3873	4036
	P_7	2789	2773	2935	2831	3614	4090	4302	4234
R_3	P_1	2468	2574	2699	2696	3038	3065	2978	3039
	P_2	3142	3400	3585	3983	3946	4287	4349	4345
	P_3	3129	3485	3776	3986	4129	4809	4924	4886
	P_4	2733	2715	2770	2683	3528	3447	3639	3630
	P_5	4429	4517	4604	4625	4493	4777	4966	4920
	P_6	2842	2845	2845	2738	3599	3869	4119	3999
	P_7	2837	2845	2837	2736	3598	3848	4466	4571

of total procedures delivered. The OD interaction is significant at the one percent level, but examination of Table 15 suggests that the significance might be attributable to the variation of O in D_1. It was decided to do an ANOVA using the same mathematical model for D_2 described earlier but with the response now being yearly total procedures delivered.

The results of this ANOVA are presented in Table 17. The

Table 16. ANOVA for Number of Procedures Delivered in Simulated Practice.

Source	SS	df	MS	F	$F_{.01}$	$F_{.05}$	
O	3,730,779	3	1,243,593	134.6	3.95	2.68	**
D	26,764,112	1	26,764,112	2,913.3	6.85	3.92	**
OD	156,431	3	52,143	5.7	3.95	2.68	**
P	59,139,040	6	9,856,506	1,072.9	2.96	2.17	**
OP	1,659,216	18	92,178	10.0	2.03	1.66	**
DP	5,473,572	6	912,262	99.3	2.96	2.17	**
ODP	1,715,319	18	95,295	10.4	2.03	1.66	**
Error	1,028,892	112	9,187				
Total	99,667,361	167					

** Significance at the 1 percent level.

significant P main effect shows that there are real differences in responses among the different levels of P. However, the main effect O was not significant, meaning that for a fixed P level, there were no statistical differences among the four levels of O. This result and the desire for comparison of this response with the net income analysis results lead to the pooling of the O responses for fixed levels of P. The pooled O responses for the seven levels of P within D_2 are:

Factor Level	Average Response
P_1	2,949
P_2	4,183
P_3	4,732
P_4	3,563
P_5	4,767
P_6	3,893
P_7	4,085

It is seen by rank order of magnitude that the treatment combinations identified previously in the net income analysis, specifically P_2, P_3, and P_5 within D_2, are again the greatest responses for numbers of procedures delivered.

Some explanation as to why the number of operatories was not significant in the ANOVA's for net income and number of procedures is called for. Under D_1 only the chairside assistant can seat and dismiss patients. The chairside assistant also is involved heavily in assisting. The availability of the chairside assistant controls the seating and dismissal of patients which, in turn, relates to the number of patients seen. In an instance where there is only one chairside assistant it would be expected that there would be little difference among the total number of procedures delivered over the range of operatories simulated since the chairside assistant "controls" the flow through the office under D_1. This is substantiated in Table 15 (see P_1, P_5, P_6, and P_7).

However, in instances where there are multiple chairside assistants (three in P_3) it would be expected that their availability to seat and dismiss patients would be greater resulting in more procedures for the same number of operatories as compared to single chairsides, and increasing numbers of procedures as more operatories are added. This again is revealed in Table 15.

Under D_2, the role flexibility of the ancillary personnel should allow more numbers of procedures to be delivered for the same personnel configuration when compared to D_1. This is shown in Table 15. Also, the same table shows that there are slight increases (though not statistically significant) in the number of procedures delivered as the number of operatories increases for a personnel configuration. This might be attributed to the dentist controlling the flow of patients through the practice. Thus, increasing numbers of operatories in the range simulated slowly increases the numbers of procedures delivered for D_2.

Two other secondary measures of effectiveness of systems response, average patient waiting time and average personnel utilization, are represented in Tables 18 and 19 respectively. Although these data are presented without analytic investigation for the reasons given in Chapter III, several resulting functional and

Table 17. ANOVA for Simulated Number of Yearly Procedures Under D_2.

Source	SS	df	MS	F	$F_{.01}$	$F_{.05}$	
O	2,085,723	3	695,241	2.14	4.13	2.76	
P	29,542,448	6	4,923,741	15.15	3.12	2.25	**
OP	12,142,171	18	674,565	2.08	2.20	1.75	*
Error	18,206,608	56	325,118				
Total		83					

* Significance at the 5% level

** Significance at the 1% level

Table 18. Average In-Chair Patient Waiting Time (Minutes).

	D_1				D_2			
	O_1	O_2	O_3	O_4	O_1	O_2	O_3	O_4
P_1	8.5	8.4	7.8	8.4	5.6	7.1	8.2	8.8
P_2	6.8	7.4	7.1	6.8	2.7	3.8	4.3	4.6
P_3	6.8	7.5	7.5	7.3	2.3	3.4	3.7	3.9
P_4	5.0	5.2	5.7	6.4	3.1	5.5	6.0	6.3
P_5	3.1	3.3	3.8	4.1	2.1	3.2	3.4	3.5
P_6	4.5	5.3	5.5	5.7	3.0	3.7	4.9	5.1
P_7	4.7	4.8	5.5	5.7	2.9	3.7	3.9	4.4

Table 19. Average Utilization of Dentist, EFA, and Chairside Assistants for Various Factor Levels.

		D_1				D_2			
		O_1	O_2	O_3	O_4	O_1	O_2	O_3	O_4
P_1	DENT	.26	.27	.27	.30	.40	.43	.46	.46
	EFA	.51	.52	.53	.53	.64	.66	.66	.66
	CSIDE	.77	.78	.79	.79	.87	.87	.88	.88
P_2	DENT	.33	.36	.38	.40	.55	.61	.62	.62
	EFA	.74	.76	.78	.78	.41	.46	.47	.48
	CSIDE	.46	.48	.50	.53	.70	.72	.74	.75
P_3	DENT	.32	.36	.39	.42	.61	.70	.71	.71
	EFA	.81	.82	.83	.83	.38	.39	.42	.42
	CSIDE	.27	.30	.32	.33	.53	.56	.57	.58
P_4	DENT	.30	.31	.31	.32	.38	.44	.49	.49
	EFA	.29	.29	.30	.32	.56	.64	.65	.66
	CSIDE	.93	.94	.94	.94	.83	.86	.86	.89
P_5	DENT	.45	.47	.47	.48	.47	.56	.58	.60
	EFA	.51	.52	.56	.57	.32	.40	.42	.42
	CSIDE	.69	.72	.71	.73	.71	.72	.73	.73
P_6	DENT	.30	.32	.30	.32	.39	.43	.46	.49
	EFA	.18	.17	.17	.19	.38	.57	.60	.61
	CSIDE	.97	.97	.97	.97	.85	.88	.89	.89
P_7	DENT	.31	.27	.31	.32	.39	.41	.44	.47
	EFA	.10	.09	.10	.11	.26	.42	.55	.56
	CSIDE	.97	.91	.97	.97	.84	.91	.92	.93

organizational matters are discussed in the paragraphs below.

In most cases average patient in-chair waiting time increases as the number of operatories increases for a specific personnel configuration. It is believed that this occurs as a result of the increasing demand for services that increasing numbers of operatories cause and the attainment of the near maximum supply of number of services capable of being delivered by the practice personnel. It was shown earlier that both net income and numbers of procedures were not significant for the main effect O for a fixed P level. This result supports the notion that a saturation of service supply may occur, thus causing approximately equal numbers of services over all levels of O for a fixed P. If this is true then this explains the increasing patient waiting times as numbers of operatories increase. That is, there are increasing numbers of patients with no available resources to serve them, and that this phenomenon is related to the number of patients idle (operatories) at any one time.

Also, with respect to average patient in-chair waiting time, it appears that D_2 in most cases exhibits lower waiting time, than D_1. This might be attributed to the interchangeability of personnel in D_2. The increased personnel idle time under D_1 would explain the subsequently longer average in-chair patient waiting times observed. Also, if this proposition is true, then the average utilization of practice personnel should be higher under D_2 than D_1.

Examination of the data reveals that the average personnel utilizations are indeed higher under D_2 than D_1. This is probably characteristic of the flexibility of the practice personnel under D_2

to substitute for an unavailable primary task performer rather than the patient and an available (but not primary) task performer being idle.

Discussion of Methodology Use

The evaluation methodology developed and illustrated in this study is intended as a problem solving tool for certain problems of dental practice management. However, its most important use is to serve as a basis for future investigative work in the utilization of EFA's and related topics. Specifically, it is suggested that only researchers associated with TEAM programs and with an adequate knowledge of the analytic techniques utilized herein study and apply this methodology.

It is envisioned that this methodology can find application in an academic environment. A dental school with a TEAM program would supply valuable feedback leading to the sophistication and refinement of the methodology. In this environment it would be possible to simulate and analyze various configurations of TEAM practices and draw working conclusions from them. Then, by actually implementing and observing the statistically "best" modeled configuration(s), valuable feedback could be obtained. This could possibly lead to new ideas of TEAM philosophy and to refinement of the evaluation methodology.

Discussion of TEAM Practice

The implications of the TEAM philosophy in dental practice drawn from this and other studies seem to indicate that operationally

TEAM practices are a reasonable alternative for increasing numbers of services delivered while maintaining high quality dentistry. In addition to high quality and quantity dental services TEAM practice seems to offer the dentist a means of maintaining a better-than-average income.

There are, of course, some questions to be answered concerning the legality of EFA utilization and acceptability of EFA's of the dental community. Presently, there are few, if any, State Dental Practice Acts which allow the delegation of some "dentist" tasks to ancillary personnel. Much more of a problem is the attutide of many contemporary dentists who feel this type of ancillary person is unwarranted. Many dentists today still do not employ chairside assistants, much less dental hygienists. This would seem to indicate that EFA utilization will not again general acceptance for some time.

Possibly, as new dental students go into practice, the newer approaches to dental care delivery, including EFA utilization, will become accepted by the dental community. It seems that TEAM practice will only achieve marginal use in dental care delivery in the near future. However, in the interim, there exists an opportunity to further investigate and sophisticate existing TEAM philosophies.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

This research was concerned with the development of a methodology for analyzing the operation of a specific type of dental practice and the demonstration of the methodology on national average practice data. The results and conclusions contained herein would be directly applicable to a dental practice which possesses the following characteristics:

1. Solo dental practices which employ at least one chairside assistant and one EFA with TEAM operating characteristics.

2. Non-specialty dental practices which operate with either decision rule one or two as described in this study.

3. An optimization criterion of net revenue derived by the dentist prior to taxes.

The paragraphs below describe the conclusions drawn for each of the three study objectives. Recommendations are then offered dealing with the application of the methodology. Insights gained about TEAM practice from the methodology demonstration are offered. Finally, areas for further study are identified.

Conclusions

The first study objective was development of a methodology for investigation of dental team composition, numbers of operatories, and other input parameters in a solo dental practice. With regard to this objective the following conclusions were reached:

1. The system description, data collection, and model development effort resulted in a simulation model which appears to be a valid representation of a solo dental practice employing TEAM personnel and operating procedures.

2. Methods of statistical analysis of the model results were selected for the identification of the significantly "best" configurations modeled.

3. It was concluded that the first objective was fulfilled.

A second objective of the study was to demonstrate the evaluation methodology on national average input data to determine the adequacy of the methodology as a predictive and evaluation tool. The conclusions below were reached with regard to this objective.

1. It was concluded from the demonstration of the methodology that the simulation model and the analysis techniques were capable of simulating and evaluating various levels of "real" input data satisfactorily.

2. It was concluded that the second research objective was accomplished.

The third objective was to investigate the results of the methodology demonstration on national data in terms of general implications for use of EFA's in solo dental practice. Specific conclusions related to this objective are given below.

1. The decision rule D_2 (which allowed for substitution of higher skill level personnel in situations wherein the primary task

performer was busy) was dominant over D_1, (which did not allow such substitutability) for the primary and all the secondary measures of effectiveness.

2. Net income, the primary effectiveness measure, and the total number of procedures delivered, a secondary effectiveness measure, were maximized for personnel configurations which had two or more chairside assistants.

3. Findings of the demonstration showed that utilization of more than two EFA's in a solo dental practice yields relatively lower dentist net income due to higher unit costs and an oversupply of EFA resources in relation to the maximum patient flow through the practice. The dentist and the chairside assistants seem to be the major factors in determining the number of procedures delivered yearly.

4. There was no clear basis for choice of the number of operatories that should be selected to maximize net income, although the "optimal" personnel configuration itself might suggest a reasonable number (or range) of operatories.

5. TEAM practice seems to offer the dentist a satisfactory means of delivering a larger number of services to patients while simultaneously producing an acceptable net income without himself being excessively busy.

6. It was concluded that the third research objective was accomplished.

Recommendations

With regard to the methodology developed for simulating and evaluating various input factors for proposed TEAM solo practices, the following recommendations are offered.

1. The methodology developed in this study seems to be a valid and useful aid in analyzing the consequences of resource allocations and expense factors in TEAM practices. It is suggested, however, that researchers or other people familiar with the techniques used in the methodology and demonstration will be required to apply this methodology successfully.

2. In any application of this methodology it is suggested that the application guide be reviewed and followed when changing input parameters or decision variables. Also, a computer comparable to or larger than the IBM 360, Model 30 should be used to run the simulation model.

Regarding the implications of TEAM solo practices derived from the demonstration of the methodology on mean national input statistics, the following recommendations are offered as general guidelines.

3. The results of this research indicate that the personnel substitution policy described by decision rule two should be utilized in the application of TEAM dentistry in practices of the type examined in this study. It was shown that such an operating policy will result in greater numbers of procedures being performed, lower average in-chair patient waiting time, higher personnel utilization, and greater net income to the dentist.

4. The results of this research and the experience gained during the course of the demonstration suggest that for dental practices similar to the illustrative practice, at least two chairside assistants

be employed when implementing and applying TEAM principles.

Recommendations for Further Study

1. Perhaps the major difficulty in an endeavor which describes and analyzes a suppler-consumer system is the establishment of a measure of effectiveness the simultaneously represents the interests of both the supplier and consumer of services. It is recommended that broad-spectrum effectiveness criteria be developed to represent mutual interests or account for trade-offs between consumer and supplier for use in future manpower planning and health policy studies.

2. This and other simulation research efforts have identified personnel operating dynamics (operating policies) as a very important factor contributing to the system response. Investigation and simulation of more sophisticated interpersonnel dynamics (e.g., EFA assisting another EFA) might lead to substantial increases in effectiveness measures such as net income, personnel utilization, and numbers of procedures performed.

3. Substantial gains might be realized by increasing the number of dentists or by altering the EFA skill inventory to include more dental tasks. It is recommended that an appropriate area for future research be the investigation of group dental practice personnel configurations and the implications of altering the personnel skill inventories.

APPENDIX A

GPSS MODEL LISTING

Model 1

Decision Rule One

```
        REALLOCATE XAC,30,BLC,920,FAC,1,STO,4,QUE,1
        REALLOCATE LOG,0,TAB,0,FUN,1,VAR,9,FSV,42
        REALLOCATE HSV,0,CHA,0,GRP,0,BVR,0,FMS,0,HMS,0
*       SIMULATE
        STORAGE    S$OPERA,5/S$CSIDE,2/S$SUITE,5/S$EFA,2
        UNLIST
*
*
 OPERA  STARTMACRO
 #A     ASSIGN     1,#B
        ASSIGN     2,#C
        ASSIGN     3,#D
        ASSIGN     4,#E
        ASSIGN     5,#F
        ASSIGN     6,#G
        ASSIGN     7,#H
        ASSIGN     8,#I
        TRANSFER   .600,,*+5
        TRANSFER   .500,,*+6
        TRANSFER   .500,,*+7
        ASSIGN     10,K4
        TRANSFER   ,*+6
        ASSIGN     10,K1
        TRANSFER   ,*+4
        ASSIGN     10,K2
        TRANSFER   ,*+2
        ASSIGN     10,K3
        ASSIGN     11,P10
        ASSIGN     12,P10
        ASSIGN     13,P10
        ASSIGN     14,P10
        ASSIGN     15,P10
        ASSIGN     16,P10
        TRANSFER   #J,*+8,*+1
        ADVANCE    296,FN1
        SAVEVALUE  P1+,K1
        SAVEVALUE  30+,*2
        SAVEVALUE  32+,K87
        SAVEVALUE  33+,K1
        LOOP       10,*-4
        TRANSFER   ,EFA1
        ADVANCE    296,FN1
        SAVEVALUE  P1+,K1
        SAVEVALUE  32+,K87
        LOOP       10,*-2
        TRANSFER   ,EFA3
        ENDMACRO
*
*
 NORML  STARTMACRO
 #A     ASSIGN     1,#B
        ASSIGN     2,#C
        ASSIGN     3,#D
        ASSIGN     4,#E
```

```
        ASSIGN      5,#F
        ASSIGN      6,#G
        ASSIGN      7,#H
        ASSIGN      8,#I
        TRANSFER    #J,*+7,*+1
        SAVEVALUE   30+,*2
        SAVEVALUE   33+,K1
        SAVEVALUE   P1+,K1
        SAVEVALUE   32+,K87
        ADVANCE     296,FN1
        TRANSFER    ,EFA1
        SAVEVALUE   P1+,K1
        SAVEVALUE   32+,K87
        ADVANCE     296,FN1
        TRANSFER    ,EFA3
        ENDMACRO
1       FUNCTION    RN1,C24
0         0   .1     .104 .2      .222 .3      .355 .4      .509 .5      .69
.6      .915 .7     1.2   .75   1.38  .8     1.6   .84   1.83  .88   2.12
.9     2.3   .92    2.52  .94   2.81  .95    2.99  .96   3.2   .97   3.5
.98    3.9   .99    4.6   .995  5.3   .998   6.2   .999    7   .9997   8
      1 VARIABLE    K978*X30/K1000-V2     COLLECTION RATIO
      2 VARIABLE    K13264+X32
      3 VARIABLE    X34*K2                  CONVERT TO ONE YEAR
      4 VARIABLE    QT$INSER/K120         AVERAGE PATIENT WAITING TIME
      5 VARIABLE    FR$DENT/K120          AVERAGE DENTIST VTILIZATION
      6 VARIABLE    SR$CSIDE/K120         AVERAGE AUXILIARY UTILIZATION
      7 VARIABLE    SR$OPERA/K120         AVERAGE OPERATORY UTILIZATION
      8 VARIABLE    SR$SUITE/K120         AVERAGE SUITE UTILIZATION
      9 VARIABLE    SR$EFA/K120
        GENERATE    ,,28800,1    COST  CALCULATIONS AND MODEL TERMINATION
        SAVEVALUE   34+,V1        INCREMENT DAILY INCOME
        SAVEVALUE   35,V3         CONVERT TO ONE YEAR
        SAVEVALUE   37+,V4        AVERAGE PATIENT WAITING TIME
        SAVEVALUE   38+,V5        AVERAGE DENTIST VTILIZATION
        SAVEVALUE   39+,V6        AVERAGE AUXILIARY UTILIZATION
        SAVEVALUE   40+,V7        AVERAGE OPERATORY UTILIZATION
        SAVEVALUE   41+,V8        AVERAGE SUITE UTILIZATION
        SAVEVALUE   9+,V9
        TERMINATE   1
        GENERATE    ,,14400,1,1  LUNCH TIME BREAK
        PREEMPT     DENT,PR,ZIP,,RE
        ADVANCE     3600
        RETURN      DENT
        TERMINATE
        GENERATE    1200,,,,,16     GENERATE A PATIENT ARRIVAL EVERY 20 MIN
        ASSIGN      10,K1
        ASSIGN      11,K1
        ASSIGN      12,K1
        ASSIGN      13,K1
        ASSIGN      14,K1
        ASSIGN      15,K1
        ASSIGN      16,K1
        GATE  SNF   SUITE,STOP
```

```
       ENTER       SUITE          ENTER OFFICE
       TRANSFER    BOTH,THIS,THAT
THIS   GATE SNF    CSIDE
       GATE SNF    OPERA
       TRANSFER    SIM,,*-2
       ENTER       CSIDE
       ENTER       OPERA
       ADVANCE     280,FN1     TRANSIT TO OPERATORY & SEAT & DRAPE
       QUEUE       INSER
       GATE NU     DENT,*+6
       SEIZE       DENT
       DEPART      INSER
       ADVANCE     60,FN1
       LEAVE       CSIDE
       TRANSFER    ,*+31
       LEAVE       CSIDE
       GATE NU     DENT
       GATE SNF    CSIDE
       TRANSFER    SIM,,*-2
       SEIZE       DENT
       ENTER       CSIDE
       ADVANCE     60,FN1
       LEAVE       CSIDE
       TRANSFER    ,*+22
THAT   GATE SNF    EFA
       GATE SNF    OPERA
       TRANSFER    SIM,,*-2
       ENTER       EFA
       ENTER       OPERA
       ADVANCE     280,FN1
       QUEUE       INSER
       GATE NU     DENT,*+6
       SEIZE       DENT
       DEPART      INSER
       ADVANCE     60,FN1
       LEAVE       EFA
       TRANSFER    ,*+9
       LEAVE       EFA
       GATE NU     DENT
       GATE SNF    EFA
       TRANSFER    SIM,,*-2
       SEIZE       DENT
       ENTER       EFA
       ADVANCE     60,FN1
       LEAVE       EFA
       TRANSFER    .403,,RESTO    RESTORATIVE
       TRANSFER    .500,,DIAGN    DIAGNOSTIC
       TRANSFER    .380,,PREVE    PREVENTIVE
       TRANSFER    .460,,ORSUG    ORAL SURGERY
       TRANSFER    .200,,OTHRR    EMERGENCY TREATMENT
       TRANSFER    .750,,PROST    PROSTHODONTICS
       TRANSFER    .500,,PERIO    PERIODONTICS
       TRANSFER    .200,,ORTHO    ORTHODONTICS
       TRANSFER    ,ENDOD         ENDODONTICS
```

```
*
* PROCEDURES DELIVEREC ACCORDING TO TRANSFER PROBABILITIES
*
 RESTO TRANSFER    .620,,AMALG   AMALGAM RESTORATION
       TRANSFER    .490,,SYNTH   SYNTHETIC
       TRANSFER    .270,,ONLAY   GOLD ONLAY
       TRANSFER    .420,,JCKET   PORCELAIN JACKET
       TRANSFER    .820,,CROWN   GOLD CROWN
       TRANSFER    .333,,TEMPO   TEMPORARY CROWN
       TRANSFER    .500,,RECEM   RECEMENTATION
       TRANSFER    ,EPOST        ENDODONTIC POST
*
*
*
*
*
 EFA1  QUEUE       INSER
       RELEASE     DENT
       TEST NE     P3,KO,HERE
       TRANSFER    BOTH,GOEFA,GODEN
 GOEFA GATE SNF    EFA
       ENTER       EFA
       GATE SNF    CSIDE
       ENTER       CSIDE
       ADVANCE     60,FN1
       DEPART      INSER
       ADVANCE     *3,FN1
       LOOP        11,*-1
       TEST NE     P4,KO,CEASE
       LEAVE       EFA
       LEAVE       CSIDE
       TRANSFER    ,*+12
 GODEN GATE NU     DENT
       SEIZE       DENT
       GATE SNF    CSIDE
       ENTER       CSIDE
       ADVANCE     60,FN1
       DEPART      INSER
       ADVANCE     *3,FN1
       LOOP        11,*-1
       TEST NE     P4,KO,OUT
       LEAVE       CSIDE
       RELEASE     DENT
 DENT2 QUEUE       INSER
 HERE  GATE NU     DENT
       SEIZE       DENT
       TRANSFER    BOTH,TRYCS,TRYEF
 TRYCS GATE SNF    CSIDE
       ENTER       CSIDE
       TRANSFER    ,*+11
 TRYEF GATE SNF    EFA
       ENTER       EFA
       ADVANCE     60,FN1
       DEPART      INSER
```

```
        ADVANCE    *4,FN1
        LOOP       12,*-1
        TEST NE    P5,K0,EXIT
        LEAVE      EFA
        RELEASE    DENT
        TRANSFER   ,*+8
        ADVANCE    60,FN1
        DEPART     INSER
        ADVANCE    *4,FN1
        LOOP       12,*-1
        TEST NE    P5,K0,OUT
        LEAVE      CSIDE
        RELEASE    DENT
EFA2    QUEUE      INSER
        TRANSFER   BOTH,TOEFA,TODEN
TOEFA   GATE SNF   EFA
        ENTER      EFA
        GATE SNF   CSIDE
        ENTER      CSIDE
        ADVANCE    60,FN1
        DEPART     INSER
        ADVANCE    *5,FN1
        LOOP       13,*-1
        TEST NE    P6,K0,CEASE
        LEAVE      EFA
        LEAVE      CSIDE
        TRANSFER   ,*+12
TODEN   GATE NU    DENT
        SEIZE      DENT
        GATE SNF   CSIDE
        ENTER      CSIDE
        ADVANCE    60,FN1
        DEPART     INSER
        ADVANCE    *5,FN1
        LOOP       13,*-1
        TEST NE    P6,K0,OUT
        LEAVE      CSIDE
        RELEASE    DENT
DENT3   QUEUE      INSER
        GATE NU    DENT
        SEIZE      DENT
        TRANSFER   BOTH,USECS,USEEF
USECS   GATE SNF   CSIDE
        ENTER      CSIDE
        TRANSFER   ,*+8
USEEF   GATE SNF   EFA
        ENTER      EFA
        ADVANCE    60,FN1
        DEPART     INSER
        ADVANCE    *6,FN1
        LOOP       14,*-1
        TRANSFER   ,EXIT
        ADVANCE    60,FN1
        DEPART     INSER
```

```
        ADVANCE    *6,FN1
        LOOP       14,*-1
        TRANSFER   ,CUT
EFA3    QUEUE      INSER
        RELEASE    DENT
        TRANSFER   BOTH,ATEFA,ATDEN
ATEFA   GATE SNF   EFA
        ENTER      EFA
        GATE SNF   CSIDE
        ENTER      CSIDE
        ADVANCE    60,FN1
        DEPART     INSER
        ADVANCE    *7,FN1
        LOOP       15,*-1
        TEST NE    P8,K0,CEASE
        LEAVE      EFA
        LEAVE      CSIDE
        TRANSFER   ,*+12
ATDEN   GATE NU    DENT
        SEIZE      DENT
        GATE SNF   CSIDE
        ENTER      CSIDE
        ADVANCE    60,FN1
        DEPART     INSER
        ADVANCE    *7,FN1
        LOOP       15,*-1
        TEST NE    P8,K0,CUT
        LEAVE      CSIDE
        RELEASE    DENT
DENT4   QUEUE      INSER
        GATE NU    DENT
        SEIZE      DENT
        TRANSFER   BOTH,GETCS,GETEF
GETCS   GATE SNF   CSIDE
        ENTER      CSIDE
        TRANSFER   ,*+8
GETEF   GATE SNF   EFA
        ENTER      EFA
        ADVANCE    60,FN1
        DEPART     INSER
        ADVANCE    *8,FN1
        LOOP       16,*-1
        TRANSFER   ,EXIT
        ADVANCE    60,FN1
        DEPART     INSER
        ADVANCE    *8,FN1
        LOOP       16,*-1
        TRANSFER   ,CUT
OPERA   MACRO      AMALG,8,1415,486,438,558,0,198,0,.500
OPERA   MACRO      SYNTH,10,1307,588,360,972,0,0,0,.999
NORML   MACRO      ONLAY,11,1530,372,1272,1566,252,522,1332,.500
NORML   MACRO      JCKET,12,8299,588,960,1566,252,372,1145,.500
NORML   MACRO      CROWN,13,7133,372,918,2010,252,372,732,.500
NORML   MACRO      EPOST,16,2868,372,2970,1566,252,372,732,.500
```

```
 NORML MACRO        RECEM,15,954,288,0,0,0,0,0,.999
 NORML MACRO        TEMPO,14,2509,372,2250,0,0,0,0,.999
*
*
 DIAGN TRANSFER     .350,,IEXAM
       TRANSFER     .910,EMERG,PEXAM
 NORML MACRO        IEXAM,1,832,0,378,2586,0,0,0,.999
 NORML MACRO        EMERG,3,986,0,378,0,0,0,0,.999
 NORML MACRO        PEXAM,2,970,0,378,294,0,0,0,.999
*
*
 PREVE TRANSFER     .880,,PROPH
       TRANSFER     .750,MGUAR,TOPFL
*
*
 NORML MACRO        PROPH,4,913,984,0,0,0,0,0,.999
 NORML MACRO        TOPFL,5,663,600,0,0,0,0,0,.999
 NORML MACRO        MGUAR,6,434,0,612,0,0,0,0,.999
*
*
 ORSUG TRANSFER     .900,SUREX,SIMEX
 SIMEX TRANSFER     .280,ONETH,MULTH
 NORML MACRO        ONETH,24,1464,0,144,246,0,0,0,.999
 NORML MACRO        MULTH,25,2949,0,480,426,0,426,330,.500
 NORML MACRO        SUREX,26,4869,0,3186,246,0,426,330,.500
*
*
 NORML MACRO        OTHRR,28,1800,0,1698,0,0,0,0,.999
*
*
 PROST TRANSFER     .270,,DENTU
       TRANSFER     .730,REPAR,BRIDG
 DENTU TRANSFER     .250,,NUMB1
       TRANSFER     .330,,NUMB2
       TRANSFER     .500,NUMB3,NUMB4
 NORML MACRO        NUMB1,21,6709,318,252,564,894,0,0,.999
 NORML MACRO        NUMB2,21,0,0,0,0,0,216,0,.001
 NORML MACRO        NUMB3,21,0,0,0,0,0,2124,2532,.001
 NORML MACRO        NUMB4,21,0,0,0,0,0,636,948,.001
 NORML MACRO        REPAR,23,1976,0,636,0,0,0,0,.999
 BRIDG TRANSFER     .333,,NUMBA
       TRANSFER     .500,NUMBB,NUMBC
 NORML MACRO        NUMBA,22,16889,318,1836,2376,252,0,0,.999
 NORML MACRO        NUMBB,22,0,0,0,0,0,150,4944,.001
 NORML MACRO        NUMBC,22,0,0,0,0,0,2076,0,.001
*
*
 PERIO TRANSFER     .550,OSSEO,GING
 NORML MACRO        OSSEO,20,7424,0,3588,246,0,426,0,.500
 NORML MACRO        GING,19,4876,0,5100,246,0,426,0,.500
*
*
 NORML MACRO        ORTHO,27,13447,0,996,0,0,0,0,.999
*
```

```
*
 ENDOD TRANSFER    .140,CANAL,PULPO
 CANAL TRANSFER    .330,,UNO
       TRANSFER    .500,DEUX,TROIS
 NORML MACRO       PULPO,17,4939,372,720,0,0,0,0,.999
 NORML MACRO       UNO,18,8924,666,894,0,0,0,0,.999
 NORML MACRO       DEUX,18,0,0,0,0,0,996,3072,.001
 NORML MACRO       TROIS,18,0,0,0,0,0,996,1764,.001
*
*
 CEASE LEAVE       EFA
       ADVANCE     600,FN1
       LEAVE       CSIDE
       TRANSFER    ,*+8
 OUT   RELEASE     DENT
       ADVANCE     600,FN1
       LEAVE       CSIDE
       TRANSFER    ,*+4
 EXIT  RELEASE     DENT
       ADVANCE     600,FN1
       LEAVE       EFA
 ZIP   LEAVE       OPERA
       LEAVE       SUITE
 STOP  TERMINATE
       START       1,NP
       RMULT       331
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
       START       1,NP
       RMULT       333
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
       START       1,NP
       RMULT       335
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
       START       1,NP
       RMULT       337
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
```

```
        CLEAR     X1-X28,X33-X41
        START     1,NP
        CLEAR     X1-X28,X33-X41
        START     1,NP
        CLEAR     X1-X28,X33-X41
        START     1,NP
        CLEAR     X1-X28,X33-X41
        START     1,NP
        CLEAR     X1-X28,X33-X41
        START     1
        REPORT
SAV     TITLE     33,TOTAL NUMBER INITIAL PROCEDURES
        SPACE     2
SAV     TITLE     35,NET YEAR INCOME
        SPACE     2
SAV     TITLE     37,AVERAGE PATIENT WAITING TIME
        SPACE     2
SAV     TITLE     38,AVERAGE DENTIST UTILIZATION
        SPACE     2
SAV     TITLE     39,AVERAGE CHAIRSIDE ASSISTANT UTILIZATION
        SPACE     2
SAV     TITLE     40,AVERAGE OPERATORY UTILIZATION
        SPACE     2
SAV     TITLE     41,AVERAGE SUITE UTILIZATION
        SPACE     2
SAV     TITLE     9,AVERAGE EFA UTILIZATION
        END
```

Model 2

Decision Rule Two

```
// JOB SP822     GPSS
// ASSGN SYS000,X'131'
// EXEC DAR01V2
        REALLOCATE XAC,50,BLO,870,FAC,1,STO,4,QUE,1
        REALLOCATE LCG,0,TAB,0,FUN,1,VAR,9,FSV,42
        REALLOCATE HSV,0,CHA,0,GRP,0,BVR,0,FMS,0,HMS,0
*       SIMULATE
        STORAGE     S$OPERA,5/S$CSIDE,2/S$SUITE,5/S$EFA,2
        UNLIST
*
*
 OPERA  STARTMACRO
 #A     ASSIGN      1,#B
        ASSIGN      2,#C
        ASSIGN      3,#D
        ASSIGN      4,#E
        ASSIGN      5,#F
        ASSIGN      6,#G
        ASSIGN      7,#H
        ASSIGN      8,#I
        TRANSFER    .600,,*+5
        TRANSFER    .500,,*+6
        TRANSFER    .500,,*+7
        ASSIGN      10,K4
        TRANSFER    ,*+6
        ASSIGN      10,K1
        TRANSFER    ,*+4
        ASSIGN      10,K2
        TRANSFER    ,*+2
        ASSIGN      10,K3
        ASSIGN      11,P10
        ASSIGN      12,P10
        ASSIGN      13,P10
        ASSIGN      14,P10
        ASSIGN      15,P10
        ASSIGN      16,P10
        TRANSFER    #J,*+8,*+1
        ADVANCE     296,FN1
        SAVEVALUE   P1+,K1
        SAVEVALUE   30+,*2
        SAVEVALUE   32+,K87
        SAVEVALUE   33+,K1
        LOOP        10,*-4
        TRANSFER    ,EFA1
        ADVANCE     296,FN1
        SAVEVALUE   P1+,K1
        SAVEVALUE   32+,K87
        LOOP        10,*-2
        TRANSFER    ,EFA3
        ENDMACRO
*
*
 NORML  STARTMACRO
 #A     ASSIGN      1,#B
```

```
         ASSIGN      2,#C
         ASSIGN      3,#D
         ASSIGN      4,#E
         ASSIGN      5,#F
         ASSIGN      6,#G
         ASSIGN      7,#H
         ASSIGN      8,#I
         TRANSFER    #J,*+7,*+1
         SAVEVALUE   30+,*2
         SAVEVALUE   33+,K1
         SAVEVALUE   P1+,K1
         SAVEVALUE   32+,K87
         ADVANCE     296,FN1
         TRANSFER    ,EFA1
         SAVEVALUE   P1+,K1
         SAVEVALUE   32+,K87
         ADVANCE     296,FN1
         TRANSFER    ,EFA3
         ENDMACRO
 1       FUNCTION    RN1,C24
 0         0   .1     .104 .2     .222 .3     .355 .4     .509 .5     .69
.6       .915 .7     1.2   .75   1.38  .8    1.6   .84   1.83  .88   2.12
.9      2.3   .92    2.52  .94   2.81  .95   2.99  .96   3.2   .97   3.5
.98     3.9   .99    4.6   .995  5.3   .998  6.2   .999   7    .9997  8
       1 VARIABLE    K978*X30/K1000-V2       COLLECTION RATIO
       2 VARIABLE    K13264+X32
       3 VARIABLE    X34*K2                   CONVERT TO ONE YEAR
       4 VARIABLE    QT$INSER/K120           AVERAGE PATIENT WAITING TIME
       5 VARIABLE    FR$DENT/K120            AVERAGE DENTIST VTILIZATION
       6 VARIABLE    SR$CSIDE/K120           AVERAGE AUXILIARY UTILIZATION
       7 VARIABLE    SR$OPERA/K120           AVERAGE OPERATORY UTILIZATION
       8 VARIABLE    SR$SUITE/K120           AVERAGE SUITE UTILIZATION
       9 VARIABLE    SR$EFA/K120
         GENERATE    ,,28800,1    COST  CALCULATIONS AND MODEL TERMINATION
         SAVEVALUE   34+,V1        INCREMENT DAILY INCOME
         SAVEVALUE   35,V3         CONVERT TO ONE YEAR
         SAVEVALUE   37+,V4        AVERAGE PATIENT WAITING TIME
         SAVEVALUE   38+,V5        AVERAGE DENTIST VTILIZATION
         SAVEVALUE   39+,V6        AVERAGE AUXILIARY UTILIZATION
         SAVEVALUE   40+,V7        AVERAGE OPERATORY UTILIZATION
         SAVEVALUE   41+,V8        AVERAGE SUITE UTILIZATION
         SAVEVALUE   9+,V9
         TERMINATE   1
         GENERATE    ,,14400,1,1  LUNCH TIME BREAK
         PREEMPT     DENT,PR,ZIP,,RE
         ADVANCE     3600
         RETURN      DENT
         TERMINATE
         GENERATE    900,,,,,16      GENERATE A PATIENT ARRIVAL EVERY 15 MIN
         ASSIGN      10,K1
         ASSIGN      11,K1
         ASSIGN      12,K1
         ASSIGN      13,K1
         ASSIGN      14,K1
```

```
       ASSIGN      15,K1
       ASSIGN      16,K1
       GATE  SNF   SUITE,STOP
       ENTER       SUITE          ENTER OFFICE
       GATE  SNF   OPERA
       GATE  SNF   CSIDE
       TRANSFER    SIM,,*-2
       ENTER       OPERA          PATIENT OBTAINS OPERATORY
       ENTER       CSIDE          ASSISTANT AVAILABLE
       ADVANCE     60,FN1         TRANSIT OF BOTH TO OPERATORY
       ADVANCE     220,FN1        SEAT AND DRAPE PATIENT
       QUEUE       INSER
       GATE NU     DENT,*+5
       SEIZE       DENT
       DEPART      INSER
       ADVANCE     60,FN1
       TRANSFER    ,*+9
       LEAVE       CSIDE
       GATE NU     DENT
       GATE SNF    CSIDE
       TRANSFER    SIM,,*-2
       SEIZE       DENT
       ENTER       CSIDE
       DEPART      INSER
       ADVANCE     60,FN1
       TRANSFER    .403,,RESTO    RESTORATIVE
       TRANSFER    .500,,DIAGN    DIAGNOSTIC
       TRANSFER    .380,,PREVE    PREVENTIVE
       TRANSFER    .460,,ORSUG    ORAL SURGERY
       TRANSFER    .200,,OTHRR    EMERGENCY TREATMENT
       TRANSFER    .750,,PROST    PROSTHODONTICS
       TRANSFER    .500,,PERIO    PERIODONTICS
       TRANSFER    .200,,ORTHO    ORTHODONTICS
       TRANSFER    ,ENDOD         ENDODONTICS
*
* PROCEDURES DELIVERED ACCORDING TO TRANSFER PROBABILITIES
*
 RESTO TRANSFER    .620,,AMALG    AMALGAM RESTORATION
       TRANSFER    .490,,SYNTH    SYNTHETIC
       TRANSFER    .270,,ONLAY    GOLD ONLAY
       TRANSFER    .420,,JCKET    PORCELAIN JACKET
       TRANSFER    .820,,CROWN    GOLD CROWN
       TRANSFER    .333,,TEMPO    TEMPORARY CROWN
       TRANSFER    .500,,RECEM    RECEMENTATION
       TRANSFER    ,EPOST         ENDODONTIC POST
*
*
*
*
*
 EFA1  QUEUE       INSER
       TEST NE     P3,K0,HERE
       RELEASE     DENT
       GATE SNF    EFA,*+5
```

```
        ENTER       EFA
        DEPART      INSER
        ADVANCE     60,FN1
        TRANSFER    ,*+9
        LEAVE       CSIDE
        GATE SNF    EFA
        GATE SNF    CSIDE
        TRANSFER    SIM,,*-2
        ENTER       EFA
        ENTER       CSIDE
        DEPART      INSER
        ADVANCE     60,FN1
        ADVANCE     *3,FN1
        LOOP        11,*-1
        TEST NE     P4,KO,OUT
DENT2   QUEUE       INSER
        LEAVE       EFA
        GATE NU     DENT,*+5
        SEIZE       DENT
        DEPART      INSER
        ADVANCE     60,FN1
        TRANSFER    ,*+9
        LEAVE       CSIDE
        GATE NU     DENT
        GATE SNF    CSIDE
        TRANSFER    SIM,,*-2
        SEIZE       DENT
        ENTER       CSIDE
        DEPART      INSER
HERE    ADVANCE     60,FN1
        ADVANCE     *4,FN1
        LOOP        12,*-1
        TEST NE     P5,KO,EXIT
EFA2    QUEUE       INSER
        RELEASE     DENT
        GATE SNF    EFA,*+5
        ENTER       EFA
        DEPART      INSER
        ADVANCE     60,FN1
        TRANSFER    ,*+9
        LEAVE       CSIDE
        GATE SNF    EFA
        GATE SNF    CSIDE
        TRANSFER    SIM,,*-2
        ENTER       EFA
        ENTER       CSIDE
        DEPART      INSER
        ADVANCE     60,FN1
        ADVANCE     *5,FN1
        LOOP        13,*-1
        TEST NE     P6,KO,OUT
DENT3   QUEUE       INSER
        LEAVE       EFA
        GATE NU     DENT,*+5
```

```
        SEIZE      DENT
        DEPART     INSER
        ADVANCE    60,FN1
        TRANSFER   ,*+9
        LEAVE      CSIDE
        GATE NU    DENT
        GATE SNF   CSIDE
        TRANSFER   SIM,,*-2
        SEIZE      DENT
        ENTER      CSIDE
        DEPART     INSER
        ADVANCE    60,FN1
        ADVANCE    *6,FN1
        LOOP       14,*-1
        TRANSFER   ,EXIT
EFA3    QUEUE      INSER
        RELEASE    DENT
        GATE SNF   EFA,*+5
        ENTER      EFA
        DEPART     INSER
        ADVANCE    60,FN1
        TRANSFER   ,*+9
        LEAVE      CSIDE
        GATE SNF   EFA
        GATE SNF   CSIDE
        TRANSFER   SIM,,*-2
        ENTER      EFA
        ENTER      CSIDE
        DEPART     INSER
        ADVANCE    60,FN1
        ADVANCE    *7,FN1
        LOOP       15,*-1
        TEST NE    P8,K0,OUT
DENT4   QUEUE      INSER
        GATE NU    DENT,*+5
        SEIZE      DENT
        DEPART     INSER
        ADVANCE    60,FN1
        TRANSFER   ,*+9
        LEAVE      CSIDE
        GATE NU    DENT
        GATE SNF   CSIDE
        TRANSFER   SIM,,*-2
        SEIZE      DENT
        ENTER      CSIDE
        DEPART     INSER
        ADVANCE    60,FN1
        ADVANCE    *8,FN1
        LOOP       16,*-1
        TRANSFER   ,EXIT
OPERA   MACRO      AMALG,8,1415,486,438,558,0,198,0,.500
OPERA   MACRO      SYNTH,10,1307,588,360,972,0,0,0,.999
NORML   MACRO      ONLAY,11,1530,372,1272,1566,252,522,1332,.500
NORML   MACRO      JCKET,12,8299,588,960,1566,252,372,1145,.500
```

```
 NORML MACRO        CROWN,13,7133,372,918,2010,252,372,732,.500
 NORML MACRO        EPOST,16,2868,372,2970,1566,252,372,732,.500
 NORML MACRO        RECEM,15,954,288,0,0,0,0,0,.999
 NORML MACRO        TEMPO,14,2509,372,2250,0,0,0,0,.999
*
*
 DIAGN TRANSFER     .350,,IEXAM
       TRANSFER     .910,EMERG,PEXAM
 NORML MACRO        IEXAM,1,832,0,378,2586,0,0,0,.999
 NORML MACRO        EMERG,3,986,0,378,0,0,0,0,.999
 NORML MACRO        PEXAM,2,970,0,378,294,0,0,0,.999
*
*
 PREVE TRANSFER     .880,,PROPH
       TRANSFER     .750,MGUAR,TOPFL
*
*
 NORML MACRO        PROPH,4,913,984,0,0,0,0,0,.999
 NORML MACRO        TOPFL,5,663,600,0,0,0,0,0,.999
 NORML MACRO        MGUAR,6,434,0,612,0,0,0,0,.999
*
*
 ORSUG TRANSFER     .900,SUREX,SIMEX
 SIMEX TRANSFER     .280,ONETH,MULTH
 NORML MACRO        ONETH,24,1464,0,144,246,0,0,0,.999
 NORML MACRO        MULTH,25,2949,0,480,426,0,426,330,.500
 NORML MACRO        SUREX,26,4869,0,3186,246,0,426,330,.500
*
*
 NORML MACRO        OTHRR,28,1800,0,1698,0,0,0,0,.999
*
*
 PROST TRANSFER     .270,,DENTU
       TRANSFER     .730,REPAR,BRIDG
 DENTU TRANSFER     .250,,NUMB1
       TRANSFER     .330,,NUMB2
       TRANSFER     .500,NUMB3,NUMB4
 NORML MACRO        NUMB1,21,6709,318,252,564,894,0,0,.999
 NORML MACRO        NUMB2,21,0,0,0,0,0,216,0,.001
 NORML MACRO        NUMB3,21,0,0,0,0,0,2124,2532,.001
 NORML MACRO        NUMB4,21,0,0,0,0,0,636,948,.001
 NORML MACRO        REPAR,23,1976,0,636,0,0,0,0,.999
 BRIDG TRANSFER     .333,,NUMBA
       TRANSFER     .500,NUMBB,NUMBC
 NORML MACRO        NUMBA,22,16889,318,1836,2376,252,0,0,.999
 NORML MACRO        NUMBB,22,0,0,0,0,0,150,4944,.001
 NORML MACRO        NUMBC,22,0,0,0,0,0,2076,0,.001
*
*
 PERIO TRANSFER     .550,OSSEO,GING
 NORML MACRO        OSSEO,20,7424,0,3588,246,0,426,0,.500
 NORML MACRO        GING,19,4876,0,5100,246,0,426,0,.500
*
*
```

```
 NORML MACRO       ORTHO,27,13447,0,996,0,0,0,0,.999
*
*
 ENDOD TRANSFER    .140,CANAL,PULPO
 CANAL TRANSFER    .330,,UNO
       TRANSFER    .500,DEUX,TROIS
 NORML MACRO       PULPO,17,4939,372,720,0,0,0,0,.999
 NORML MACRO       UNO,18,8924,666,894,0,0,0,0,.999
 NORML MACRO       DEUX,18,0,0,0,0,0,996,3072,.001
 NORML MACRO       TROIS,18,0,0,0,0,0,996,1764,.001
*
*
 OUT   LEAVE       EFA
       TRANSFER    ,*+2
 EXIT  RELEASE     DENT
       ADVANCE     600,FN1       PREPARE OPERATORY FOR NEXT PATIENT
 ZIP   LEAVE       OPERA
       LEAVE       CSIDE
       LEAVE       SUITE
 STOP  TERMINATE
       START       1,NP
       RMULT       331
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
       START       1,NP
       RMULT       333
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
       START       1,NP
       RMULT       335
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
       START       1,NP
       RMULT       337
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
       START       1,NP
       CLEAR       X1-X28,X33-X41
       START       1,NP
       RMULT       339
       CLEAR       X1-X28,X33-X41
       START       1,NP
```

```
        CLEAR      X1-X28,X33-X41
        START      1,NP
        CLEAR      X1-X28,X33-X41
        START      1,NP
        CLEAR      X1-X28,X33-X41
         START      1
        REPORT
SAV     TITLE      33,TOTAL NUMBER INITIAL PROCEDURES
        SPACE      2
SAV     TITLE      35,NET YEAR INCOME
        SPACE      2
SAV     TITLE      37,AVERAGE PATIENT WAITING TIME
        SPACE      2
SAV     TITLE      38,AVERAGE DENTIST UTILIZATION
        SPACE      2
SAV     TITLE      39,AVERAGE CHAIRSIDE ASSISTANT UTILIZATION
        SPACE      2
SAV     TITLE      40,AVERAGE OPERATORY UTILIZATION
        SPACE      2
SAV     TITLE      41,AVERAGE SUITE UTILIZATION
        SPACE      2
SAV     TITLE      9,AVERAGE EFA UTILIZATION
        END
```

APPENDIX B

KOLMOGROV-SMIRNOV PROGRAM LISTING

```
// JOB SP822        KOLMOGOROV-SMIRNOV GOODNESS OF FIT
      REAL MULT
      DIMENSION PROB(24),MULT(24),DIST(3,200),AVG(3),FREQ(2,200)
      DATA FREQ/400*0./
      READ(1,1)  (PROB(J),J=1,24)
    1 FORMAT(12F5.0,/,12F5.0)
      READ(1,1)(MULT(J),J=1,24)
      READ(1,2) AVG
    2 FORMAT(3F5.0)
      IY = 321549
      DO 20 L=1,3
      DO 20 K=1,200
      IX=IY
      CALL RANDU(IX,IY,YFL)
      DO 10 J=1,24
      IF (YFL-PROB(J)) 11,12,10
   10 CONTINUE
   11 M=J-1
      FRACT=(YFL-PROB(M))/(PROB(J)-PROB(M))
      DIST(L,K)=(((MULT(J)-MULT(M))*FRACT)+MULT(M))*AVG(L)
      GO TO 20
   12 DIST(L,K)= MULT(J)*AVG(L)
   20 CONTINUE
      DO 30 K=1,200
   30 DIST(2,K)= DIST(3,K)+DIST(2,K)
      DO 35 L=1,2
      DO 35 K=1,200
      RNG=0.0
      DO 32 J=1,200
      RNG=RNG + 200.0
      IF(DIST(L,K).LE.RNG) GO TO 33
   32 CONTINUE
      GO TO 35
   33 FREQ(L,J)=FREQ(L,J)+1.0
   35 CONTINUE
      SUM1=0.0
      SUM2=0.0
      DO 40 J=1,200
      SUM1=SUM1+FREQ(1,J)
      SUM2=SUM2+FREQ(2,J)
   40 CONTINUE
      DO 41 J=1,200
      FREQ(1,J)= FREQ(1,J)/SUM1
      FREQ(2,J)= FREQ(2,J)/SUM2
   41 CONTINUE
      DO 42 J=1,199
      K=J+1
      FREQ(1,K)= FREQ(1,K)+FREQ(1,J)
      FREQ(2,K)= FREQ(2,K)+FREQ(2,J)
   42 CONTINUE
      DIFF=0.0
      DO 43 J=1,200
      X=ABS(FREQ(1,J)-FREQ(2,J))
      IF(X.GT.DIFF)  DIFF=X
```

```
   43 CONTINUE
      WRITE(3,3) DIFF
    3 FORMAT( '1',2X,'MAX DIFFERENCE = ',F6.3)
      WRITE(3,4)
    4 FORMAT(//,T2,'CUMULATIVE FREQUENCIES',T25,'TOTAL',T35,'SUM')
      DO 44 J=1,200
   44 WRITE(3,5) FREQ(1,J),FREQ(2,J)
    5 FORMAT(T25,F6.3,T34,F6.3)
      STOP
      END
      SUBROUTINE RANDU(IX,IY,YFL)
      IY=IX*65539
      IF(IY)5,6,6
    5 IY=IY+2147483647+1
    6 YFL=IY
      YFL=YFL*.4656613E-9
      RETURN
0     .1   .2   .3   .4   .5   .6   .7   .75  .8   .84  .88
.9    .92  .94  .95  .96  .97  .98  .99  .995 .998 .999 1.0
0     .104 .222 .355 .509 .69  .915 1.2  1.38 1.6  1.83 2.12
2.3   2.52 2.81 2.99 3.2  3.5  3.9  4.6  5.3  6.2  7.   8.
900.  500. 400.
```

APPENDIX C

METHODOLOGY APPLICATION GUIDE

The following pages describe the actions required to alter decision variable levels or the value of input parameters of the simulation model. A working knowledge of GPSS 360 programming language and statistics is assumed.

SUMMARY OF VARIABLES AND PARAMETERS

The decision variables and the input parameters capable of being altered in the simulation model are listed below.

Decision Variables	Input Parameters	
Personnel (P)	Fee Scale	Service Frequency
Operatories (O)	Salaries	Task Durations
Decision Rule (D)	Rent and Utilities	Break Distribution
	Equipment Purchases	Day Length
	Depreciation	Lunch Break
	Insurance	Days Simulated
	Miscellaneous Overhead	
	Materials and Supplies	
	Laboratory Charges	
	Collection Ratio	

GENERAL NOTES

The following general items are important to remember when changing the magnitude or configuration of model inputs. These are:

1. The model simulates 120 discrete seven hour days (not including lunch hour).

2. Fees, materials and supplies, miscellaneous overhead, and laboratory changes are assessed for each procedure.

3. All other expenses are calculated for each day simulated.

4. The simulation time unit is seconds.

ALTERATION OF DECISION VARIABLES

Changes of the decision variable levels involve two alterations in the model, the level of the new variable and the cost associated with it.

1. The personnel configurations (P) can be any combination of EFA's and chairside assistants with one dentist as long as there is at least one EFA and one chairside assistant in the personnel configuration. The "STORAGE" card in the beginning of the model allows the change to be made. If it is desired to simulate four EFA's and five chairside assistants the card would appear.

As:

STORAGE S $ CSIDE,S/S $ EFA, 4/ . . . . . .

The representation of the salaries of these personnel and the costs associated with changing numbers of operatories will be discussed later in the parameter changes.

2. Changing the number of operatories is accomplished through alteration of the magnitude of operatories on the "STORAGE" card. At least one operatory must be modeled. Thus, simulation of six operatories would cause the card to appear as:

STORAGE S $ OPERA, 6/ . . . .

3. The decision rules described earlier can be utilized by simulating Rule one on Model 1 and Rule two on Model 2. These two models are contained in Appendix A. They are identical except for the decision rule dynamics. There are no expense parameter changes required for changing from one decision rule to another.

ALTERNATION OF INPUT PARAMETERS

Prior to specific instructions for changing input parameters a discussion of several important items pertaining to this type of change are presented.

The two macros in the model describe for each type of <u>procedure</u> the fee, the per procedure costs, and the person assigned and duration of each task within a procedure. Recall that when the same person performs two sequential tasks within a procedure, the time will be reflected by the sum of the two procedure duration times (see discussion in Chapter III). The ten arguments of the macros are:

A - Procedure Name		
B - Procedure Number (Save value location)		
C - Fee minus Supplies, Materials, and Laboratory Expenses		
D - EFA Task(s) Delivery Time	First Appmt.	
E - Dentist Task(s) Delivery Time	First Appmt.	
F - EFA Task(s) Delivery Time	First Appmt.	
G - Dentist Task(s) Delivery Time	First Appmt.	
H - EFA Task(s) Delivery Time	Second Appmt.	
I - Dentist Task(s) Delivery Time	Second Appmt.	
J - Probability of the First Appmt.		

The representation of non-procedure oriented fees and expenses is accomplished through "Variable 2".
The statement:

2 VARIABLE K13264 + X32

represents that $132.64 is the total daily operating expenses of the practice. This includes personnel salaries, rent and utilities, equipment purchases, depreciation, and insurance. These figures were converted from the monthly amounts by division by 20 (the number of days in the simulated month).

1. Fee Scale

An individual fee or the fee scale for all 28 procedures may be changed by altering the C field of the appropriate macro(s).

2. Salaries

The salaries for different personnel configurations at the same salary levels as the original model or changes to the salary levels for a particular personnel configuration may be represented in the second "VARIABLE" statement.

3. Rent and Utilities, Equipment Purchases, Depreciation, and Insurance.

These expenses were represented in the model demonstration as being proportional to the number of operatories. Different magnitudes of these expenses for the same method of assessment or actual values of the expenses may be reflected in the second "VARIABLE" statement.

4. Collection Ratio

The demonstration collection ratio was set at 97.8 percent. This was represented by "VARIABLE" 1 which was

1 VARIABLE K978*X30/K1000 - V2.

This variable calculates total daily net revenue. The percent of collection may be altered by changing the first constant of this variable to the desired ratio.

5. Service Frequency

The relative frequency of major types of dental services and the relative frequency of procedures within a service category were developed in the model demonstration. Alteration of these relative frequencies could be accomplished by changing the "TRANSFER" conditional probabilities for eith a service or procedure to the desired relative frequency.

6. Task Durations

A listing of the exponential task durations used in the demonstration is presented in Table 3. Changes to any or all of these would be reflected in arguments D through I of each macro. Appendix D lists the tasks included for each procedure modeled in the demonstration.

A practice personnel who finishes a dental task takes a simulated "break" of an average length of one minute. As explained earlier in Chapter IV the duration of this break can vary around the mean from zero to eight minutes. The mean time of the break could be changed by locating each "ADVANCE" block which has "60" in the A field and changing the A field to the desired mean time.

8. Day Length

The simulated day is totally eight hours long, but includes a one hour lunch break in which nobody works. The length of the day may be regulated by changing the C field of the "GENERATE" block which appears as:

```
GENERATE    ,,28800,1
```

9. Lunch Break

The lunch break is one hour in the model. If the time the lunch hour occurs is desired to be moved, say from four hours after practicing opening time to five hours, the "GENERATE" block would look like:

GENERATE ,,18000,1,1

The duration of the lunch hour is controlled by the "ADVANCE" block after the lunch hour GENERATE block. The A field of the ADVANCE block can be changed to any length lunch break.

10. Days Simulated

Regulation of the number of days simulated is by the use of multiple "START" and "CLEAR" cards. Each pair of these cards will simulate one day. The "RMULT" card after a START card changes the initial random number seed for that run to the specified A field. Thus, by relocation of RMULT cards within the START and CLEAR cards, different random number strings are generated illustrating the random variation of the model's responses for different random number generation.

APPENDIX D

TASKS WITHIN PROCEDURES

The following pages list the individual tasks within the 28 procedures performed in the simulation model. The primary task performer was given earlier in Table 3. Where there are multiple appointments for a procedure, the tasks in each appointment are given. There were equiprobable chances for choosing one appointment among the multiple appointments for procedure.* All patients were seated and draped by an ancillary personnel.

1. Initial Exam:

   History and Exam

   Bitewing Radiographs

   Prophylaxis

   Tray Selection

   Alginate Impression

   Tray Selection

   Alginate Impression

   Oral Health Instruction

2. Periodic Exam:

   Oral Exam

   Bitewing Radiographs

3. Emergency Exam:

   Oral Exam

4. Prophylaxis:

   Prophylaxis and Scaling

   Oral Health Instruction

5. Topical Fluoride:

   Topical Fluoride Application

6. Mouth Guard:

   Mouth Guard Delivery

7. Amalgam, 1 Surface:

First:	Second:
Anesthesia	Amalgam Polished
Rubber Dam	
Simple Preparation	
Amalgam Placement	
Amalgam Carved	

8. Amalgam, 2 Surface:

First:	Second:
Anesthesia	Amalgam Polished
Rubber Dam	
Matrix Band	
Compound Preparation	

*Note: A fee was assessed only if the first appointment of a procedure was delivered.

Amalgam Placement

Amalgam Carved

9. <u>Amalgam, 3^{+} Surfaces</u>:

First:	Second:
Anesthesia	Amalgam Polished
Rubber Dam	
Matrix Band	
Complex Preparation	
Amalgam Placement	
Amalgam Carved	

10. <u>Synthetic Restoration</u>:

Shade Selection

Anesthesia

Rubber Dam

Synthetic Preparation

Base for Synthetic

Synthetic Placement

Synthetic Carved

11. <u>Gold Onlay</u>

First:	Second:
Anesthesia	Anesthesia
Rubber Dam	Rubber Dam
Onlay Preparation	Remove Temporary
Tray Selection	Casting Adaptation
Rubber Impression	Cementation
Stabilize Impression	Polishing

Temporary

12. Procelain Jacket

First:	Second:
Shade Selection	Anesthesia
Anesthesia	Rubber Dam
Rubber Dam	Remove Temporary
Jacket Preparation	Tryin
Tray Selection	Cementation
Rubber Impression	Polishing
Stabilize Impression	
Temporary Crown	

13. Gold Crown:

First	Second:
Anesthesia	Anesthesia
Rubber Dam	Rubber Dam
Crown Preparation	Tryin
Tray Selection	Cementation
Rubber Impression	Polishing
Stabilize Impression	
Bite Registration	
Temporary Crown	

14. Stainless Crown:

Anesthesia

Rubber Dam

Crown Preparation

Crown Selection

Crown Cemented

15. Recementation:

Recementation

16. Endodontic Post:

First:	Second:
Anesthesia	Anesthesia
Rubber Dam	Rubber Dam
Crown Preparation	Tryin
Dowel Preparation	Cementation
Tray Selection	
Rubber Impression	
Stabilize Impression	
Temporary Crown	

17. Pulpotomy:

Anesthesia

Rubber Dam

Preparation

Pulp Cap

Material Placement

18. Root Canal:

First:	Second:	Third:
Anesthesia	Anesthesia	Anesthesia
Periapical Radiograph	Isolation	Isolation
Isolation	Root Canal Enlargement	Temporary Removal

Root Canal Drainage	Periapical Radiograph	Fill Root Canal
	Root Canal Dressing	Periapical Radiograph
	Temporary	Temporary

19. <u>Gingivectomy</u>:

First:	Second:
Anesthesia	Suture Removal
Gingivectomy	Place Placement
Sutures	Post-Surg. Instr.
Pack Placement	
Post-Surg. Instr.	

20. <u>Osseous Surgery</u>:

First:	Second:
Anesthesia	Suture Removal
Exostosis Removal	Post-Surg. Instr.
Suture Placement	
Post-Surg. Instr.	

21. <u>Complete Denture</u>:

First:	Second:
Tray Adaptation	Shade Selection
Rubber Impression	Mold Selection
Stabilize Impression	
Estab. Occ. Plane	
Bite Regist.	
Third:	Fourth:
Tryin	Adjustment
Adjustment	Polishing

Bite Regist.

Instructions

Polishing

22. Gold Bridge:

First:	Second:	Third:
Anesthesia	Remove Temporary	Bite Registration
Abutment Prep.	Tryin	Polishing
Abutment Prep.	Adaptation	
Tray Selection	Cementation	
Rubber Impression	Polishing	
Stabilize Impression		
Bite Registration		
Temporary		
Temporary		

23. Denture Repair:

Denture Repair

24. Simple Extraction, Single:

Anesthesia

Extraction

Post-Surg. Instr.

25. Simple Extraction, Multiple:

First:	Second:
Anesthesia	Post-Surg. Exam
Extractions	Suture Removal
Sutures	Post-Surg. Instr.
Post-Surg. Instr.	

26. Surgical Extraction:

First:	Second:
Anesthesia	Post-Surg. Exam
Impaction Removed	Suture Removal
Sutures	Post-Surg. Instr.
Post-Surg. Instr.	

27. Orthodontic Appliance:

Appliance Adjustment

28. Emergency Treatment:

Emergency Procedures

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